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A VISUAL ENCYCLOPEDIA

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A VISUAL ENCYCLOPEDIA

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A VISUAL ENCYCLOPEDIA

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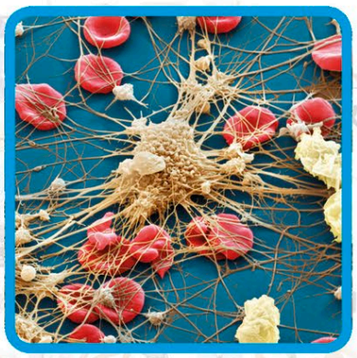

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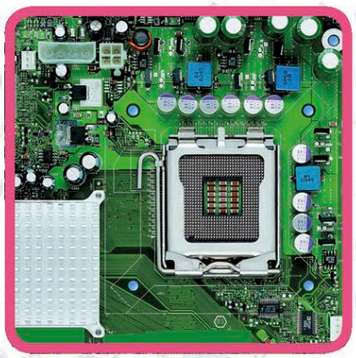

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ALBATROSS COLONY
Every year, black-browed albatrosses return to the Falkland Islands in the Atlantic Ocean to breed. This albatross colony is one of the largest in the world, with more than 500,000 birds. Each pair produces a single egg.

Nature

PLANTS

All green plants use the energy of sunlight to make sugary carbohydrate food from water and carbon dioxide in the air. This is why they grow well only in sunlit, moist places. The food fuels growth and is used to make cellulose–the tough, fibrous tissue that helps support all the various parts of the plant, from its stems and leaves to its flowers.

❶ GERMINATION
A bean plant begins life as a seed with two halves, called cotyledons. In spring when the weather is mild, the seed starts to absorb water through a minute hole in its outer coating (the testa). The seed swells, and about three days later a root grows to hold the plant in place, and a shoot appears above the ground. This process is called germination.

❷ ROOTS
The plant's roots absorb water from the soil. The water is used by the leaves to make food. The water also contains dissolved mineral salts, such as nitrates and phosphates, which are essential for growth.

❸ STEM
The strong stem of the plant supports its leaves in the sunlight. It also contains bundles of tubes or veins. These allow water containing dissolved nutrients to flow up from the roots to the leaves and also carry sugary food from the leaves to other parts of the plant.

❹ LEAVES
The leaves are the plant's food factories. They act like solar panels, as the green chlorophyll enables the plant to absorb the energy of sunlight and use it for photosynthesis—the process in which the plant takes carbon dioxide from the air and combines it with water drawn up by the roots to make sugar. Oxygen is also produced in the process and released into the air.

❺ TRANSPIRATION
As sunlight warms a plant, water in the leaves is lost as water vapor, through pores called stomata. The leaves then take in water from the stem, which in turn draws more water up into the plant from the roots. The water carries nutrients from the soil with it.

New leaves sprout from buds that form at the tips of shoots
Green chlorophyll in leaves absorbs solar energy and uses it for photosynthesis
5
4
Growing point of bean plant is at top of main stem, between leaf stalks
Leaves make sugar, which mixes with water to make sap that flows to other parts of plant
Stem is kept upright at first by water pressure but is gradually stiffened with tough cellulose
Cotyledons contain food that fuels early growth but fall off after true leaves form
Soil provides the plant with anchorage and is the main source of water and nutrients
Root network anchors plant in the soil as well as absorbing water and nutrients
3

TREES

Trees are the tallest, heaviest, and oldest of all living things. The California giant sequoia known as General Sherman weighs approximately 6,000 tons–30 times as much as the biggest animal, the blue whale. The oldest living bristlecone pine tree, which also grows in California, is nearly 5,000 years old. Yet even these ancient giants can still produce tiny seeds that grow into new trees.

LEAVES

Like all green plants, trees absorb sunlight through their leaves and use its energy to turn air and water into sugar. A tree's leaves are its food factories.

NEEDLES AND SCALES

Thin leaves make food efficiently, but they are easily damaged by hot sun or frost. So many trees that grow in very hot or cold places have thicker, tougher needles or scales.

COMPOUND LEAVES

Most trees have simple leaves of various shapes, but some have compound leaves, made up of many leaflets. These either sprout from a long stalk (pinnate) or fan out from a single point (palmate).

FRUIT

The flowers of some trees turn into juicy fruits that contain seeds. If birds eat the fruit, the seeds pass through them unharmed and are scattered far away.

FLOWERS

All trees produce flowers, but some may not be obvious because they do not have colorful petals. Other trees, however, such as apples, have showy flowers that attract insects.

TREE RINGS

Every year, a tree adds a layer of new wood to its trunk. If the tree is cut down, each year's growth shows as a visible ring, so the number of rings gives its age.

CONES

Coniferous trees such as pines have woody cones that contain small papery seeds. When the cones open up in the sun, the seeds fall out and blow away.

SEEDS AND NUTS

Some trees have tiny seeds, but others produce the bigger seeds we call nuts. Animals eat them, but also bury and forget them, so they grow into new trees.

DECIDUOUS LEAVES

Many trees lose their leaves in winter and grow new ones in spring. Before they fall, the old leaves lose their green color and turn yellow, brown, or even red.

FLOWERS

Many plants produce beautiful flowers, often vividly colored and fragrant. These intricate structures form the reproductive parts of plants and have evolved so that they attract insects and birds to sip the sugary nectar at the flower's center. While feeding, the insect or bird is dusted with pollen, which is produced by the stamens and contain the male sex cells. The pollen is deposited on the sticky stigma of another flower. This is pollination. A pollen tube then grows down the style to the ovary and fertilizes an ovule. This is fertilization. Some plants, such as grasses and many types of trees, rely on the wind to carry their pollen, and their flowers do not need showy petals or fragrant nectar to attract animals. Since this is a less efficient system, they must produce far more pollen, which can fill the air and cause hay fever.

❶ FLOWER STRUCTURE

A typical flower develops inside a bud at the end of a stalk. When the bud opens, it reveals a ring of petals, each of which secretes nectar from its base. At the center of the flower lie the male structures that produce pollen. These surround the female structures that hold the ovules, or egg cells. An outer ring of green sepals may protect the flower when it is in bud.

❷ CARPEL

An ovary, a style, and a stigma form the main parts of a carpel. At the heart of the flower lie the ovules, enclosed in a case called an ovary. The top of each ovary extends into a style that carries a sticky pad called a stigma. The flowers of some plants have many carpels, each with its own stigma, but this lily has just one.

❸ STAMEN

The tiny, dustlike pollen grains that contain the male cells are produced by stamens. These usually form a ring around the central carpel or carpels. Each stamen has a long filament, which supports a clublike anther that produces the pollen.

❹ TRANSFERRING POLLEN

Insects such as butterflies often drink nectar from one type of flower. Hummingbirds do the same, because their bills are the right shape to reach the nectar. The bird and the insect get dusted with pollen in the process and carry it directly to another flower of the same type.

❺ FERTILIZATION

If a hummingbird sips nectar from this lily, it will pick up pollen on its breast feathers. If the bird visits another lily, the sticky central stigma may pick up the pollen. Each pollen grain then sprouts a long tube that grows down through the carpel to reach an ovule. The male cell moves down the tube to fertilize the ovule so it can develop into a seed.

FRUITS

All plants produce fruits that contain their seeds. Some fruits are dry husks, but others are juicy and tasty. These attract animals, which eat them and carry the seeds in their stomachs. The tough-skinned seeds are not digested but are scattered far away from the parent plant in the animals' droppings and grow into new plants. The fruits shown here are cultivated types that have been specially bred for their size and flavor.

❶ ORANGES

An orange has very soft, juicy flesh contained in many segments, which are enclosed by a hard rind. Each segment usually contains a seed. An orange is technically a type of berry, which develops over the winter from the single ovary of an orange flower. Green at first, it turns orange as it swells to full size.

❷ BANANAS

The bananas that are cultivated in the tropics have been bred to be seedless, but the wild bananas of Southeast Asia have small fruits containing many big, hard seeds. They grow in bunches on large plants with huge leaves that sprout straight from the ground.

❸ NUTS

All nuts are large seeds, which the plant has equipped with a store of concentrated plant food. This ensures that the seedlings get a good start in life. The nut is surrounded by a hard shell, which is technically a fruit, but tough and fibrous rather than soft and juicy.

❹ DURIAN

To attract fruit-eating mammals, many fruits are fragrant. The Southeast Asian durian fruit is famous for its strong aroma, which some people like and others hate. Animals such as forest pigs and orangutans seem to love both its smell and taste.

❺ GRAPES

Some fruits such as grapes grow as clusters of soft, edible, thin-skinned berries. Each berry has several seeds embedded in its flesh, although many cultivated varieties of grapes are seedless. Berries are often vividly colored to attract birds, which have excellent color vision.

❻ PEACHES

The juicy flesh of a peach, plum, or cherry encloses a hard pit that contains a single seed. This type of fruit is called a drupe. The fleshy part is meant to be eaten, so animals spread the seeds, but some animals such as parrots can crack the pits and eat the seeds, too.

❼ FAVA BEANS

The edible part of a fava bean plant is its seeds, and its fruit is the entire pod. The wild ancestors of such beans do not attract animals. Instead, their pods dry up and split open with explosive force, so the seeds shoot out and are scattered on the ground.

❽ TOMATOES

Not all fruits are edible. Some of the wild relatives of tomatoes are extremely poisonous. They include deadly nightshade,which is lethal to humans, although some animals can eat the berries without coming to harm. Tomatoes are also related to chili peppers.

FUNGI

The mushrooms and other fungi that can appear overnight in damp places are not plants. They belong to a completely separate group of living things that feed on dead or living plants and animals. Each fungus forms a hidden network of slender stems called a mycelium, and the visible part is just the "fruiting body" that sprouts like an apple on a tree to spread the spores that grow into new fungi.

❶ OAK BOLETE

A typical mushroom has radiating gills beneath its cap that produce millions of spores. Other fungi, like the oak bolete, have spongy undersides that release spores from tiny holes or are covered with spore-producing tufts.

❷ TURKEY TAIL

Fungi are vital to life because they break down and recycle dead organisms. The turkey tail grows on dead wood, rotting it down so the nutrients it contains can be used by growing plants.

❸ DEATH CAP

Some fungi are extremely poisonous if they are eaten. The well-named death cap has probably been responsible for 90 percent of all known deaths from mushroom poisoning.

❹ SAFFRON MILK CAP

Many fungi grow around the roots of certain plants and provide them with plant foods in exchange for sugars. The saffron milk cap, for example, always grows with pine trees.

❺ PARASOL MUSHROOM

Some fungi, like the penny bun and parasol mushroom, are good to eat. But if you are not an expert at identifying them, you could be poisoned by a killer like the death cap.

❻ FLY AGARIC

The fly agaric is one of the best-known "toadstools"—a word often used for inedible or poisonous fungi. The white scales on its red cap are the remains of a thin veil that covered the growing fungus.

❼ PENNY BUN

The rootlike fibers attached to the stem are just a tiny part of the penny bun's mycelium. This can cover huge areas. The mycelium of a single honey fungus can extend 1.6 million sq ft (150,000 sq m).

❽ STUMP PUFFBALL

Puffballs are named for the way the ripe fungi puff clouds of dustlike spores when they are kicked or hit by rain. Just one giant puffball can contain an amazing 7 trillion (7,000,000,000,000) spores.

ANIMAL KINGDOM

All living things fall into one of five categories, or "kingdoms": bacteria, protists (single-celled organisms), fungi, plants, and animals. The animal kingdom is made up of many groups of invertebrates (animals without backbones, such as insects) and a few groups of vertebrates, such as mammals. They all share the ability to move and sense their surroundings and the need to find food.

❶ INSECTS

Small animals with hard external skeletons, all insects have six legs when adult and, in most cases, two pairs of wings. They include creatures such as butterflies, wasps, flies, and beetles. Many are attractive, but some can sting, bite, and carry deadly diseases.

This silver-washed fritillary butterfly has bright wing markings

❷ WORMS

There are many types of worms. They include tapeworms, which live inside other animals, flatworms, and roundworms. Most familiar are segmented worms like the earthworms that burrow in soil, marine worms that live on tidal shores, and leeches.

❸ AMPHIBIANS

Soft-skinned amphibians, such as frogs and toads, lose body moisture easily. To keep from drying out, nearly all frogs live in damp places, often near a pond. Most lay their eggs in water or other damp places, and these hatch into fishlike young, such as tadpoles.

A leech lives by sucking the blood of its victims

Sticky pads on the frog's toes give good grip

❹ BIRDS

These highly specialized, warm-blooded vertebrates are superbly equipped for flight, and some may stay airborne for most of their lives. They are the only animals with feathers, which prevent them from losing body heat, enable them to fly, and are often brightly colored.

❺ MAMMALS

Like birds, mammals are warm-blooded vertebrates, meaning they can control their body temperature. The females feed their young on milk. Most eat plants, but some, such as lions, are meat eaters. Humans belong to the mammal group.

❻ ARACHNIDS

The spiders, scorpions, ticks, and their relatives are eight-legged invertebrates with hard external skeletons but no wings. Spiders kill their prey with venomous fangs, and scorpions have stings in their tails, some of which are powerful enough to kill a human.

The red-kneed tarantula has eight legs for walking and two chelicerae (mouthparts) to hold its prey

❼ MOLLUSKS

Most mollusks are soft-bodied animals that live in water and have protective shells. They include mussels, clams, and whelks. The only mollusks able to live on land are the snails and slugs. Octopuses and squids are also mollusks, but they are highly evolved, with well-developed brains and eyes.

Lion's paw has soft pads for running and sharp, retractable claws

Suckers on each arm help the octopus move around and grab prey

❽ CRUSTACEANS

Like insects, crustaceans have hard external skeletons with several segments and strong jointed legs. All are aquatic, aside from wood lice. They include tough-shelled animals like crabs and lobsters as well as more delicate shrimps and water fleas.

The powerful claws of this lobster can seize and crush prey

❿ FISH

Fish were the first vertebrates and the ancestors of all amphibians, reptiles, mammals, and birds. They are perfectly adapted for life in water, which supports their bodies and provides them with vital oxygen. There are two main fish groups: those with bony skeletons and the sharks and rays, which have skeletons of flexible cartilage.

⓬ REPTILES

Although cold-blooded like amphibians, reptiles such as snakes and lizards have waterproof, scaly skins that allow them to live in dry places such as deserts. Most are active hunters, and some snakes have powerful venom, which they use to kill their prey and for defense, if threatened.

❾ MYRIAPODS

Named for their many legs, myriapods have long bodies divided into segments. Centipedes have a single pair of legs on each segment, while millipedes have two pairs. Some millipedes have more than 90 segments and more than 180 pairs of legs. Millipedes eat mainly dead material, but centipedes are speedy hunters.

A millipede's legs are moved by a wavelike action of the body

⓫ ECHINODERMS

Sea urchins, starfish, feather stars, and sea cucumbers are echinoderms, meaning "spiny skinned." Their bodies tend to be wheel-shaped, with a central mouth. Feather stars trap food that floats through their feathery arms, but most search for food on the seabed.

Like other reptiles, snakes have scaly skin

PLANKTON

The sunlit surface waters of many oceans teem with life, most of it microscopic, that drifts with the currents. The whole drifting community is called the plankton. It is made up of plantlike phytoplankton, which use the energy of sunlight to make food from carbon dioxide and water, and zooplankton—animals that feed on both the phytoplankton and each other. This image shows the plankton in a splash of seawater, magnified more than 25 times.

This cyanobacterium is a coiled chain of cells that make food from water and dissolved gas

CYANOBACTERIA

Once known as "blue-green algae," these simple organisms were among the first forms of life to appear on Earth, more than 3,500 million years ago. They still flourish in the oceans where, like diatoms, they turn carbon dioxide and water into sugary carbohydrates.

DIATOMS

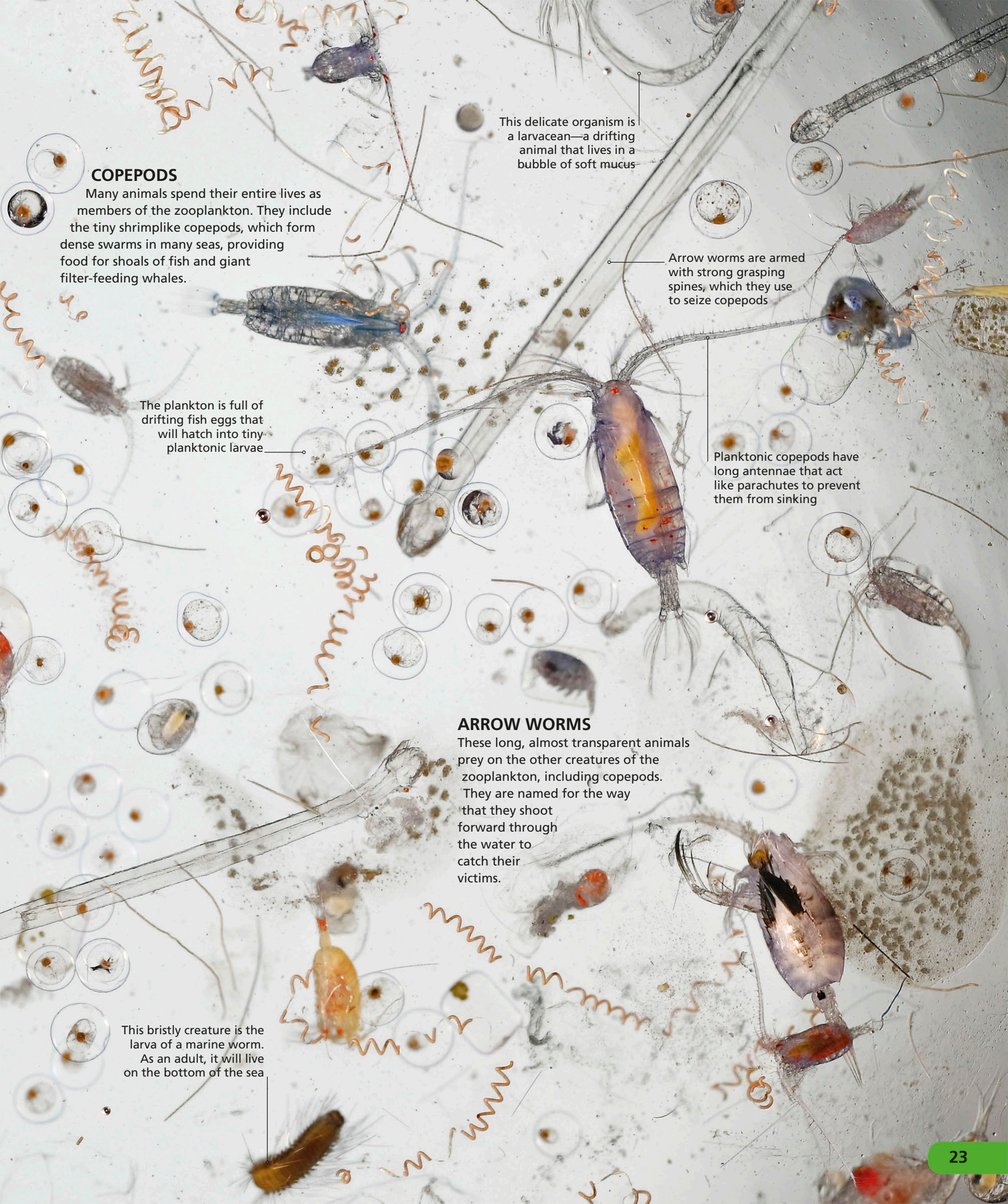
The phytoplankton consist of microscopic organisms such as diatoms and cyanobacteria. Diatoms have shells of glassy silica that fit together like tiny boxes with lids, and they exist in a dazzling variety of forms. They thrive in cool seas, where they turn the water gray-green and often multiply into vast cloudy "blooms" that are visible from space.

The glassy shell of this diatom reveals the green structures that use solar energy to make food

CRAB LARVA

Among the members of the zooplankton are the eggs and young of animals that have very different shapes and lives when adult. They include the eggs of reef corals and infant fish, mollusks, and crustaceans like this crab larva. Drifting in the plankton provides them with food and helps them disperse through the oceans to find new places to live.

The size of a rice grain, this crab larva is light enough to drift near the surface in the plankton



COPEPODS

Many animals spend their entire lives as members of the zooplankton. They include the tiny shrimplike copepods, which form dense swarms in many seas, providing food for shoals of fish and giant filter-feeding whales.

ARROW WORMS

These long, almost transparent animals prey on the other creatures of the zooplankton, including copepods. They are named for the way that they shoot forward through the water to catch their victims.

INSECTS

Insects are the most successful creatures on Earth. Beetles alone account for almost a third of all known animal species. Many insects are tiny, but others are big enough for us to see the amazing intricacy of their structure. Some may bite or sting, and a few are real pests, but most are harmless, fascinating, and beautiful.

BUTTERFLIES

Butterflies start life as leaf-munching caterpillars, then form protective cases and become pupae, before turning into colorful winged beauties that sip nectar from flowers.

MOTHS

Moths are basically the same as butterflies, but most moths fly by night on whirring wings. Many are dull brown for camouflage, but a few are brightly patterned.

FLIES

True flies have just two wings for flying, rather than four like other adult insects. Some are biting bloodsuckers, and a few can spread diseases, but others like hoverflies are harmless.

WASPS AND BEES

Although notorious for their stings, most wasps and bees are no trouble. Wasps hunt insects to feed their young, while bees visit flowers to gather nectar.

ANTS

All ants form huge colonies ruled over by a single "queen ant" that lays all the eggs. The "worker ants" build the nest, defend it, and gather food.

BEETLES

Most beetles can be recognized by the hard, shiny wing cases that hide their delicate wings. Some have long horns or jaws, especially the males, which use them for fighting.

INSECT ANATOMY

Many insects start life as soft-skinned grubs, or larvae, but eventually they all turn into adults with hard, segmented bodies and six jointed legs. Their skin is toughened with a substance called chitin, which is a bit like hard plastic, so it acts as an external skeleton. It is often shiny and brightly colored, but it can look furry or scaly. Most adult insects like this wasp also have wings made from sheets of chitin, powered by muscles inside their bodies.

❶ ANTENNAE

An insect's long antennae help it feel its way, but they are mainly used to detect scent. They are covered with sensitive nerve endings that pick up chemical signals. The antennae of some moths can detect scents from more than half a mile (1 km) away.

❷ HEAD

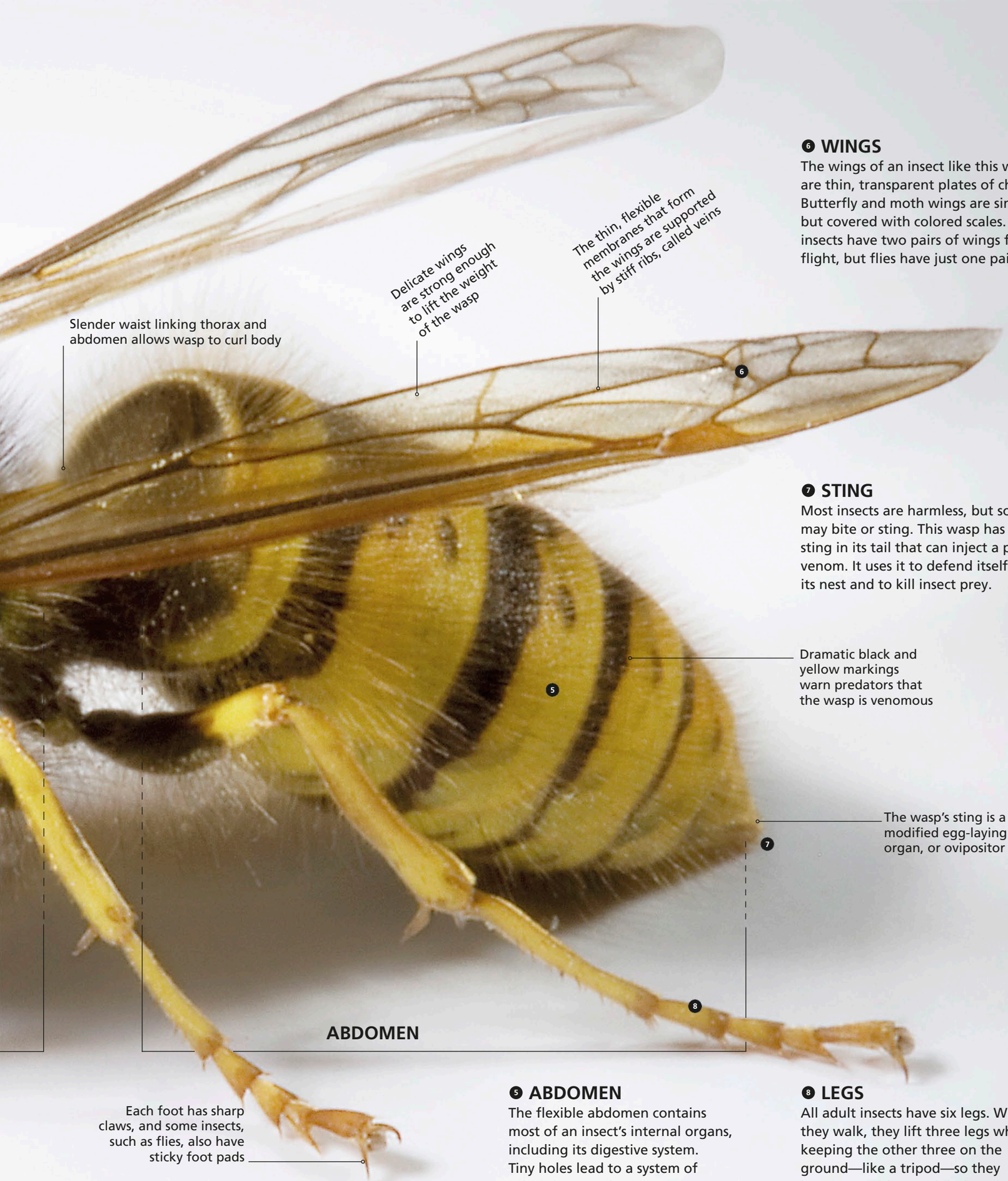
An insect's head contains its brain and carries most of its sense organs. It is also equipped with mouthparts that are specialized to deal with its diet. A mosquito has a sharp needle for sucking blood, while this wasp has stout jaws for chewing other insects.

❸ EYES

Like many other insects, an adult wasp has two large compound eyes. Each has hundreds of tiny lenses that see the world as a mosaic of colored dots. A wasp also has three small simple eyes, which are called ocelli, on the top of its head.

❹ THORAX

The legs and wings of an insect are attached to the front section of its body, the thorax. This is packed with wing muscles, which power the wings rather like someone in a rowing boat using a pair of oars. It also contains the insect's crop, used to store food.



❻ WINGS

The wings of an insect like this wasp are thin, transparent plates of chitin. Butterfly and moth wings are similar but covered with colored scales. Most insects have two pairs of wings for flight, but flies have just one pair.

❼ STING

Most insects are harmless, but some may bite or sting. This wasp has a sting in its tail that can inject a painful venom. It uses it to defend itself and its nest and to kill insect prey.

❺ ABDOMEN

The flexible abdomen contains most of an insect's internal organs, including its digestive system. Tiny holes lead to a system of tubes that supply air to its organs and muscles. The vivid stripes of this wasp warn other animals that it can sting.

❽ LEGS

All adult insects have six legs. When they walk, they lift three legs while keeping the other three on the ground—like a tripod—so they have no problem with balance. Each leg is a series of stiff tubes, hinged together and powered by muscles inside the tubes.

FISH

Fish were the first animals with backbones to appear on Earth, more than 500 million years ago. They have since evolved into a wonderful variety of forms. From powerful sharks to delicate seahorses, fish now make up more than half of all vertebrate species. Most fish live in the salty oceans, like those shown below, but many–including the fish on the opposite page–live in freshwater lakes and rivers. A few, such as salmon, are able to live in both.

❸ FORCEPS FISH

A type of butterflyfish that lives on the coral reefs of the Indian and Pacific Oceans, the forceps fish has a highly elongated snout with a very small mouth at the tip. The fish uses this to pick tiny animals from coral crevices and from the spines of sea urchins.

❺ PUFFERFISH

Pufferfish defend themselves by inflating their bodies with water so they are hard for predators to swallow. Some species have sharp spines that add to the effect, and many of their internal organs contain lethal poisons.

❶ RAY

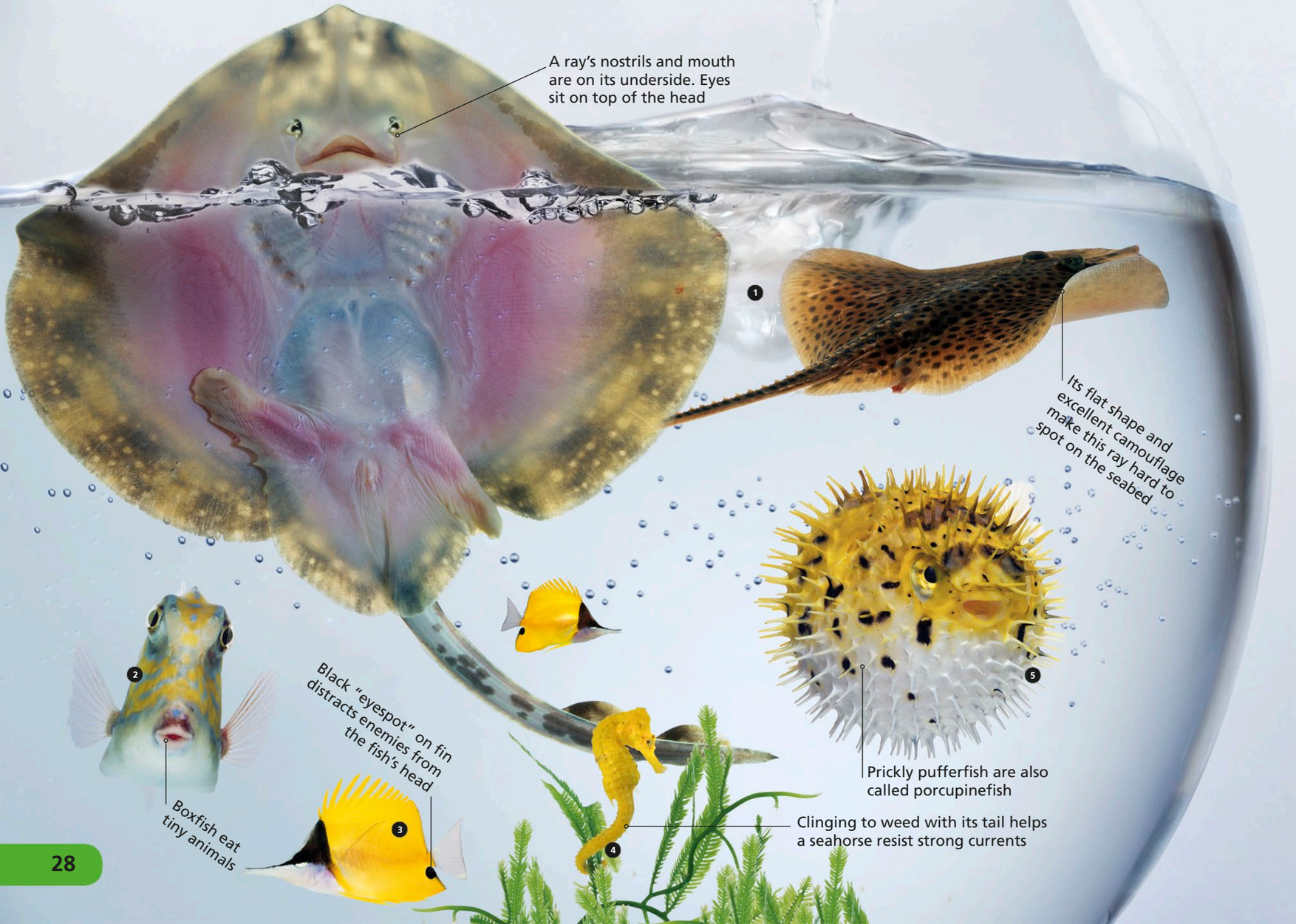
Closely related to sharks, with skeletons made of cartilage, rays are flattened fish that swim by using their pectoral (side) fins like wings. They live on the seabed, hunting smaller fish and shellfish.

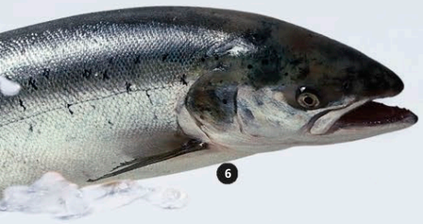
❷ BOXFISH

The curious boxfish are named for their boxlike defensive armor, formed from thick, fused scales. This prevents all body movement, so the fish swim by using their small fins like oars.

❹ SEAHORSE

These strange fish owe their name to their horselike heads. They live in shallow seas, where they cling to aquatic plants with their tails. The male "incubates" the female's eggs in a pouch on his belly.





❻ SALMON
Big, powerful salmon spend most of their lives at sea but swim upstream to the shallow rivers with gravelly bottoms where they breed. They have adaptations that allow them to move between fresh and salt water.

❼ CARP
Able to live in water that has very little oxygen, carp are well equipped for life in warm, still lakes and ponds. They feed by using their extendible jaws to root around on the bottom for small animals and aquatic plants.

❽ VELVET CICHLID
Better known by its common name, Oscar, this species lives in slow-flowing South American rivers and digs in the riverbeds for small animals such as worms and freshwater shrimp. There are currently 1,721 species of cichlids known.

❾ STICKLEBACK
This fish gets its name from the sharp spines on its back. It lives in ponds, rivers, and lakes and some shallow seas. In spring, the male makes a nest of plant fiber and does a dance to attract females to lay their eggs.

❿ PIKE
This powerful hunter lives in lakes and slow-flowing rivers throughout Europe, northern Asia, and North America. Pike hunt fish and waterbirds by lying in wait among aquatic plants and darting out to seize victims.

⓫ PIRANHA
Notorious for its sharp teeth, this South American predator mainly preys on other fishes but may strip the meat from larger carcasses of dead animals.

Three sharp spines help defend the stickleback from bigger predatory fish

Tough, shiny scales help protect the carp's skin from injury and attack by parasites

The colors of this cichlid are variable, changing as the fish grows older

Long, pointed jaws have big, sharp teeth to give the pike a good grip on slippery prey

Piranhas stick together in shoals for safety

FEEDING

All animals get the nutrients they need by eating plants, animals, or other organisms such as bacteria or fungi. Some of these foods are easy to find but hard to digest, like leaves and grass. Others, such as animal prey, can be difficult to find or catch but are easy to digest and rich in food value. Animals have developed a variety of adaptations for gathering and digesting their food. Some of these are much more specialized than others and govern the animal's whole way of life.

❶ BASKING SHARK

The enormous basking shark has tiny teeth. It feeds by swimming through swarms of tiny drifting organisms with its mouth gaping open and trapping them in its sievelike gills. Many whales filter feed in a similar way, as do some birds, such as flamingos.

❷ GIRAFFE

A giraffe's extra long neck allows it to eat leaves that other animals cannot reach. Like many leaf eaters and grass eaters, giraffes have bacteria in their digestive system, which break down the tough plant fiber to release vital nutrients.

❸ LEECH

A parasitic leech clings to a living animal, slices into its skin, and sucks its blood. Some leeches may take up to five times their own weight in blood but need to feed only once or twice a year.

❹ PARROT

Birds need concentrated food that does not weigh them down, so most birds feed on insects, meat, fruit, or seeds. Many parrots eat nuts, cracking the strong shells with their powerful hooked bills, but some have brush-tipped tongues to lap up sugary flower nectar.

❺ LION

Catching large live animals can be difficult and dangerous. A lion relies on its strength and long, sharp canine teeth to kill its prey. It slices the meat into mouthfuls with scissorlike cheek teeth but swallows it without chewing because meat is easy to digest.

❻ GIANT ANTEATER
Many animals eat insects, but few are so specialized for the job as the giant anteater. It has a long, sticky, wormlike tongue, which it flicks in and out of its long snout up to 150 times a minute to scoop its tiny prey from their nest.

❼ TAPEWORM
This parasite lives in the intestines of another animal—including some people. Since it is surrounded by predigested food, it does not need a digestive system of its own, or even a mouth, and it just soaks up nutrients through its thin skin.

A housefly can contaminate food by walking on it

❽ EGYPTIAN VULTURE
Many creatures are scavengers that feed on carrion (dead flesh) and other scraps. They include the Egyptian vulture, which clears up remains that would otherwise simply rot. Without scavengers, the world would be a lot less healthy.

❾ HOUSEFLY
Many insects, including all flies, can eat only liquid food. Some suck blood or gather nectar or plant juices. The housefly can also liquefy some solid foods such as sugar by drenching them with saliva and soaking up the result with its moplike mouthparts.

❿ BROWN BEAR
Although basically a meat eater, the brown bear devours many foods, ranging from meat and fish to fruit and honey. This means that it is not specialized for any particular way of feeding and can change its food with the seasons. Humans have the same "omnivorous" (eat-all) diet.

CRUSTACEANS

This varied group of invertebrates includes around 67,000 known species. Crustaceans take their name from the hard, jointed shells, or exoskeletons, that support and protect their bodies. Most crustaceans live in the sea, or in freshwater lakes and rivers, but wood lice and some species of crab live permanently on land. Crustaceans have at least four pairs of jointed legs, gills for breathing under water, and sensory antennae that they use to feel and smell the things around them.

❶ CRAB

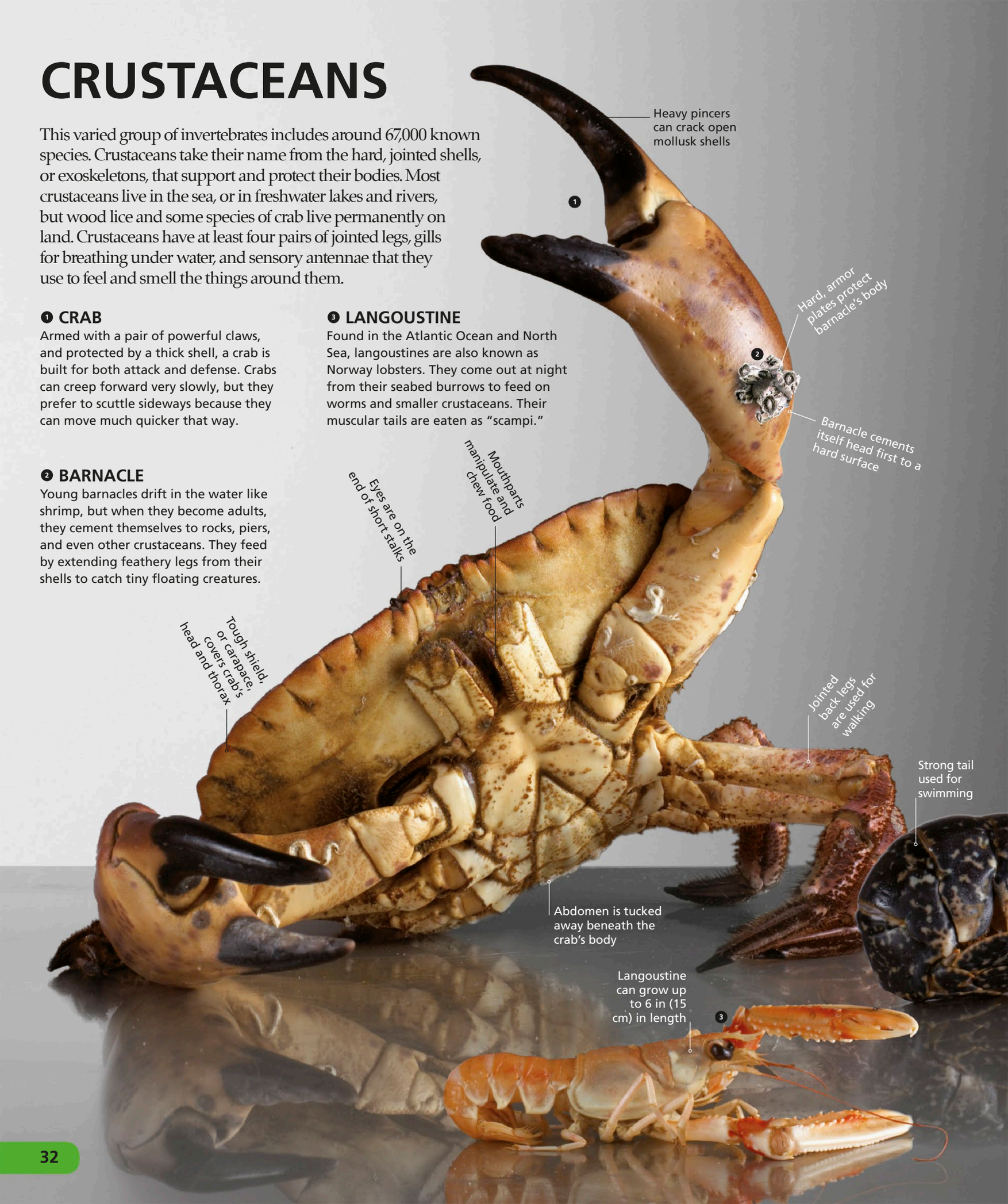
Armed with a pair of powerful claws, and protected by a thick shell, a crab is built for both attack and defense. Crabs can creep forward very slowly, but they prefer to scuttle sideways because they can move much quicker that way.

❷ BARNACLE

Young barnacles drift in the water like shrimp, but when they become adults, they cement themselves to rocks, piers, and even other crustaceans. They feed by extending feathery legs from their shells to catch tiny floating creatures.

❸ LANGOUSTINE

Found in the Atlantic Ocean and North Sea, langoustines are also known as Norway lobsters. They come out at night from their seabed burrows to feed on worms and smaller crustaceans. Their muscular tails are eaten as "scampi."



❹ LOBSTER

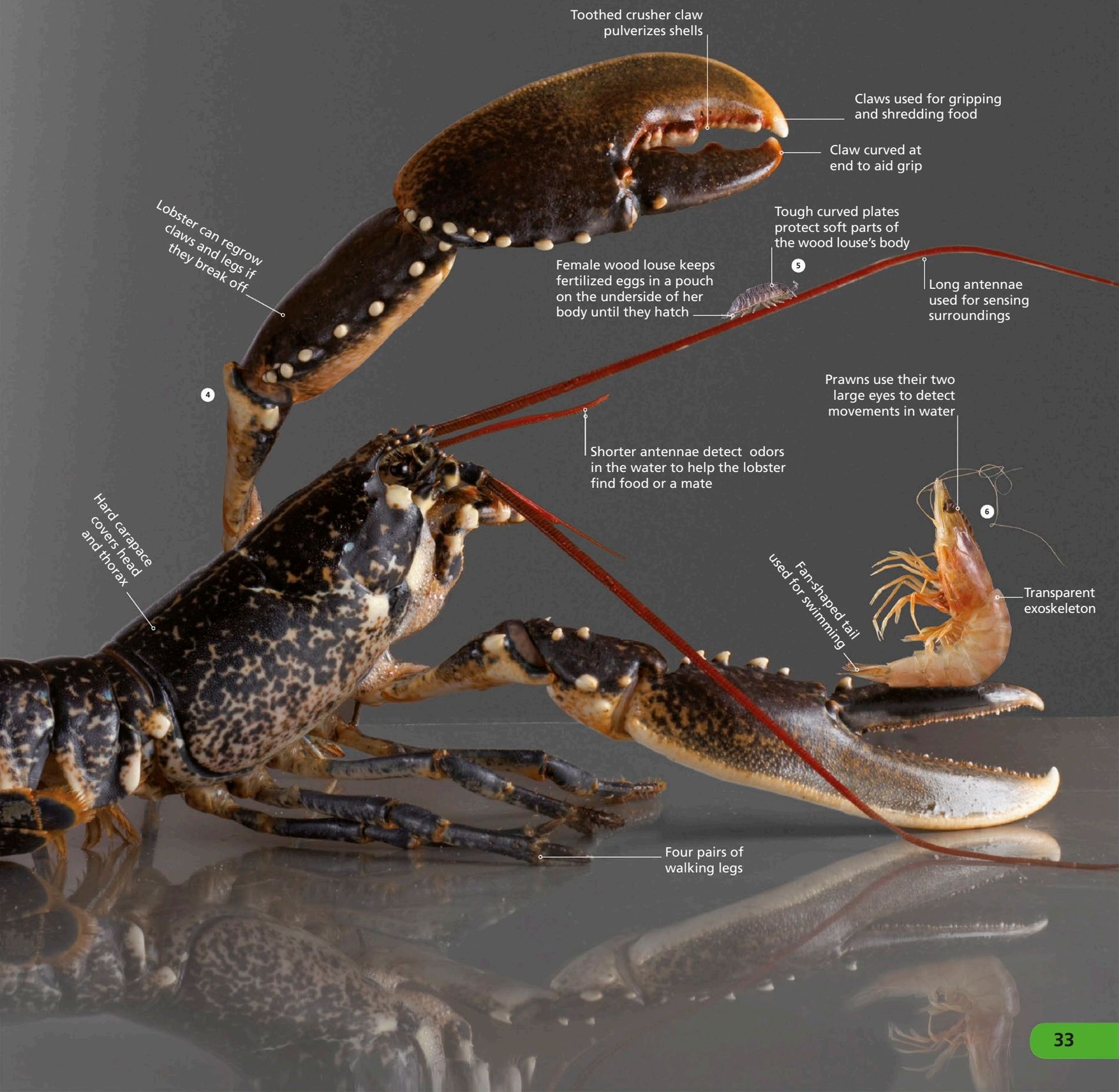
Weighed down by their heavy shells, lobsters usually walk on the seabed, but they can swim backward to escape danger by flipping their tails. Like all crustaceans, they have to molt (shed) their hard exoskeletons several times as they grow.

❺ WOOD LOUSE

Wood lice are among the only crustaceans that are completely at home on land, but they must live in damp places. They have seven pairs of legs, and some species can roll themselves into a ball if they feel threatened. Despite their name, they do not damage wood.

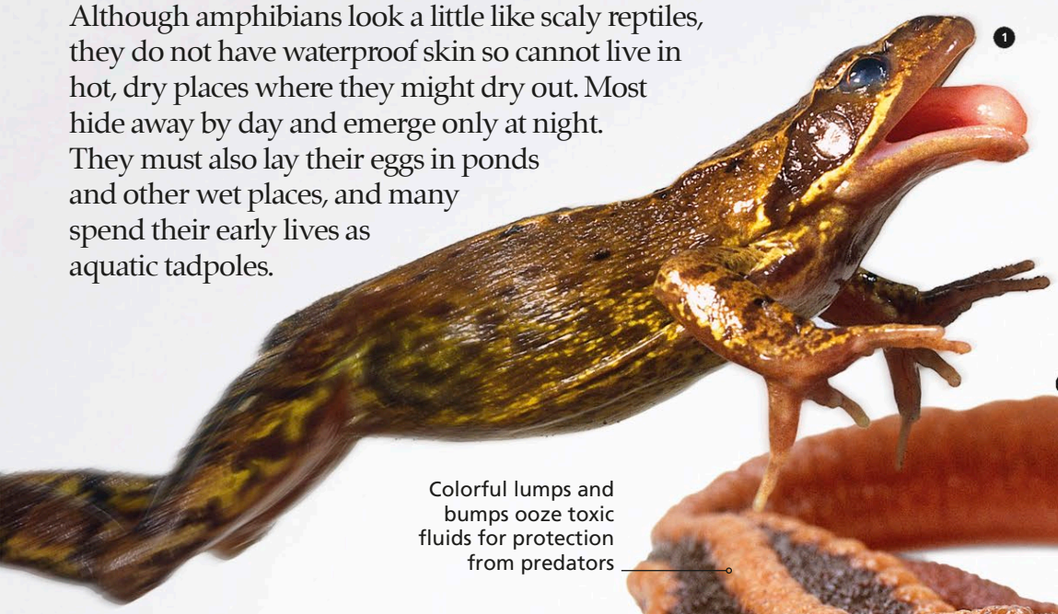
❻ PRAWN

Many prawns and shrimp swim or drift in the water, but others spend most of their lives searching for food on the seabed. Some specialize in picking bloodsucking parasites off the fish that live on coral reefs, which line up to be cleaned.



AMPHIBIANS

Although amphibians look a little like scaly reptiles, they do not have waterproof skin so cannot live in hot, dry places where they might dry out. Most hide away by day and emerge only at night. They must also lay their eggs in ponds and other wet places, and many spend their early lives as aquatic tadpoles.



❶ COMMON FROG

All amphibians eat live animals, which they hunt by sight. The frog on the left is leaping through the air to catch a ladybug, which it will snap up and swallow alive.

Common frogs are able to lighten or darken their skin to blend in with their surroundings

European common frogs

❼ Mandarin salamander

Colorful lumps and bumps ooze toxic fluids for protection from predators

❹ MIDWIFE TOAD

Most frogs and toads lay their eggs in water, but the male midwife toad wraps the strings of eggs around his legs and looks after them until they are ready to hatch.

Midwife toad

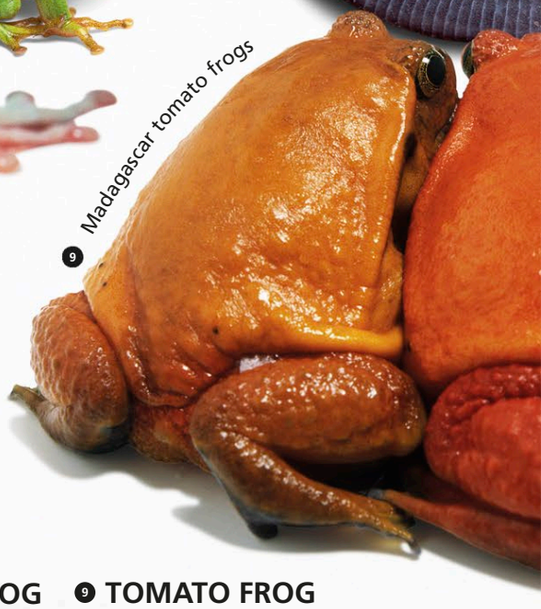
Tinker vine frog

Caecilian ❿

Frog's thin, moist skin can absorb oxygen directly from the air

Australian tree frog

Madagascar tomato frogs ❾



Big eyes help poison dart frogs see well in the dark forest

Poison dart frog

❻ POISON DART FROG

Tiny tree frogs of American tropical forests are protected by powerful poisons on their skin. Some are so deadly that local people use them to make poison darts.

❼ MANDARIN SALAMANDER

Salamanders and newts are a bit like frogs with long tails. Some, like the Asian mandarin salamander, have vividly colored skin that warns enemies that they are poisonous to eat.

❽ AUSTRALIAN TREE FROG

Tree frogs have suckers on the tips of their toes so that they can cling to wet foliage. Most tree frogs only visit pools of water to breed.

❾ TOMATO FROG

Many frogs and toads, like these tomato frogs, defend themselves by inflating their bodies with air so that they are harder to eat.

❷ TADPOLES

Nearly all frogs start life in the water as tadpoles with long tails and no legs. Gradually they grow legs, hop out of the water, and their tails shrivel away.

❸ AFRICAN BULLFROG

A mouse makes a tasty snack for a bullfrog, which will eat almost anything that moves.

❺ FOAM-NESTING FROG

Some tree frogs keep their eggs moist by laying them in a nest of wet foam high in the trees.

❿ CAECILIAN

Wormlike caecilians burrow in tropical forests by pushing their bony heads through the soil. They have no legs and are almost blind.

⓫ FOUR-EYED FROG

A four-eyed frog has a pair of big eyespots on its back. If attacked, it turns its back and inflates its body so that it looks like a fierce animal.

⓬ FIRE SALAMANDER

Bright patterns warn predators that this salamander can spray a blinding poison up to 13 ft (4 m) through the air.

LIFE CYCLES

All animals pass through different stages of life as they grow into fully developed adults. The first stage is the start of a new life, and for most animals the final phase is when they breed to start the cycle over again. For some animals, such as most mammals, these stages are very similar. For others, such as many insects, every stage is quite different and involves a complete transformation, or metamorphosis, from the previous stage.

1 Blind and helpless, a newborn puppy cannot eat solid food, so it lives on its mother's milk.

2 For the first two weeks, the puppy cannot see the world around it.

3 After about two weeks, the puppy can see, but its digestive system can still cope with only milk.

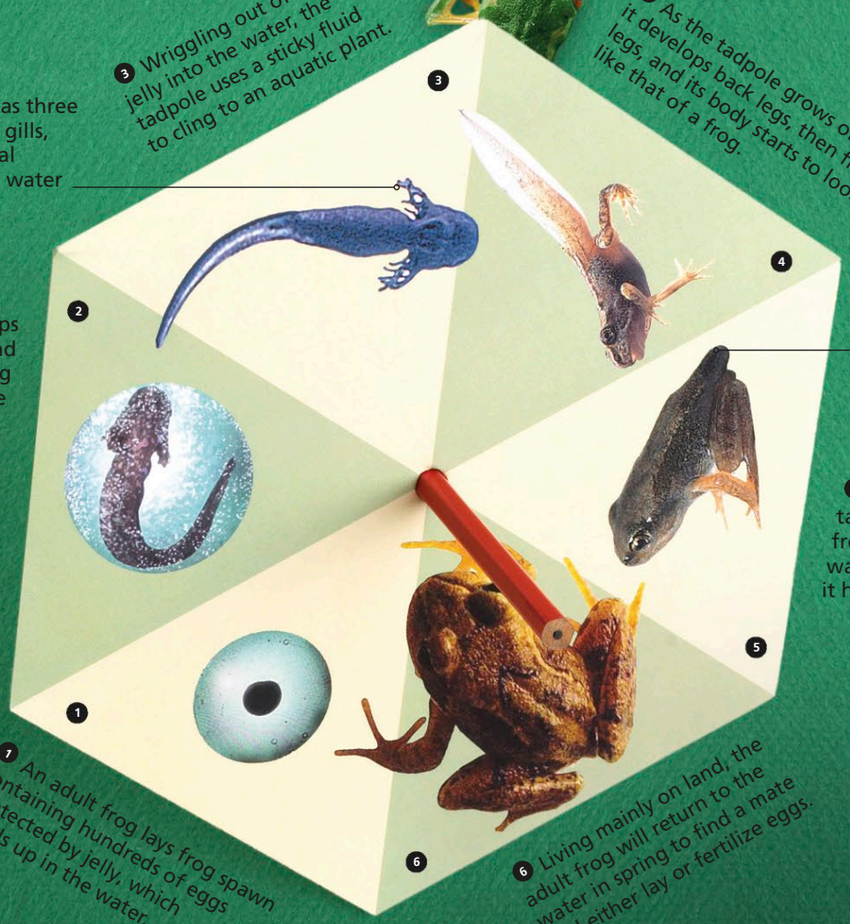
4 The older puppy can eat solid food provided by its mother and begins to learn vital skills through play.

5 Though not able to breed just yet, this young dog can find its own food.

6 The fully grown dog now looks to find a mate to produce puppies of its own.

DOG ▶

A dog's life cycle is typical of many mammals, because it starts life as a smaller version of its parents. As it grows bigger, its internal organs develop so it can eat an adult diet and eventually produce its own young.



1 An adult frog lays frog spawn containing hundreds of eggs protected by jelly, which swells up in the water.

2 An embryo develops inside the egg and starts to move, using energy supplied by the yolk of the egg.

3 Wriggling out of the jelly into the water, the tadpole uses a sticky fluid to cling to an aquatic plant.

Young tadpole has three pairs of feathery gills, which absorb vital oxygen from the water

4 As the tadpole grows older, it develops back legs, then front legs, and its body starts to look like that of a frog.

Tail shrinks to a stump as the froglet learns to use its legs to swim and hop

5 Lungs develop, the tail shrinks, and the new froglet hops out of the water to live on land, where it hunts small animals.

6 Living mainly on land, the adult frog will return to the water in spring to find a mate and either lay or fertilize eggs.

◀ FROG

Most amphibians, such as frogs, have complex life cycles. A typical frog lays eggs in water, and these hatch out as fishlike tadpoles. The tadpoles develop lungs and legs and hop out of the water as tiny froglets, eventually becoming fully grown adult frogs.

❶ An adult female lays her eggs on a carefully chosen plant, and a tiny larva, or caterpillar, hatches from each egg.

❷ By eating ravenously, the baby caterpillar grows fast. It sheds its tough skin several times as it gets bigger.

❸ The full-grown caterpillar has a fat, soft body full of stored energy, which will fuel its metamorphosis into an adult.

Caterpillar sheds its colorful skin to emerge as a legless, pale-looking pupa

❹ The caterpillar stops feeding and becomes a pupa—the stage of its life cycle when it is transformed into a winged adult.

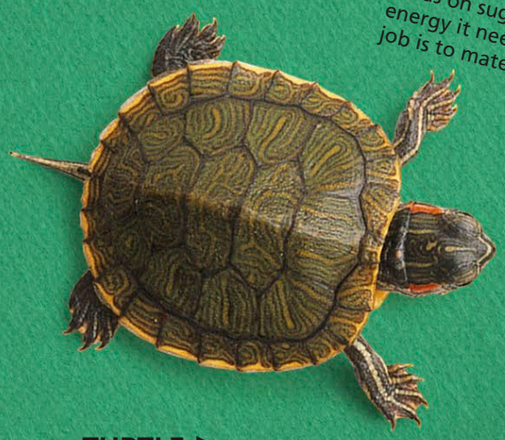
Pupa splits open, and crumpled butterfly crawls out

❺ The pupa stays motionless for several weeks while the caterpillar inside is taken apart and rebuilt as a butterfly.

❻ After emerging, the butterfly feeds on sugary nectar to get the energy it needs to fly, but its main job is to mate and lay eggs.

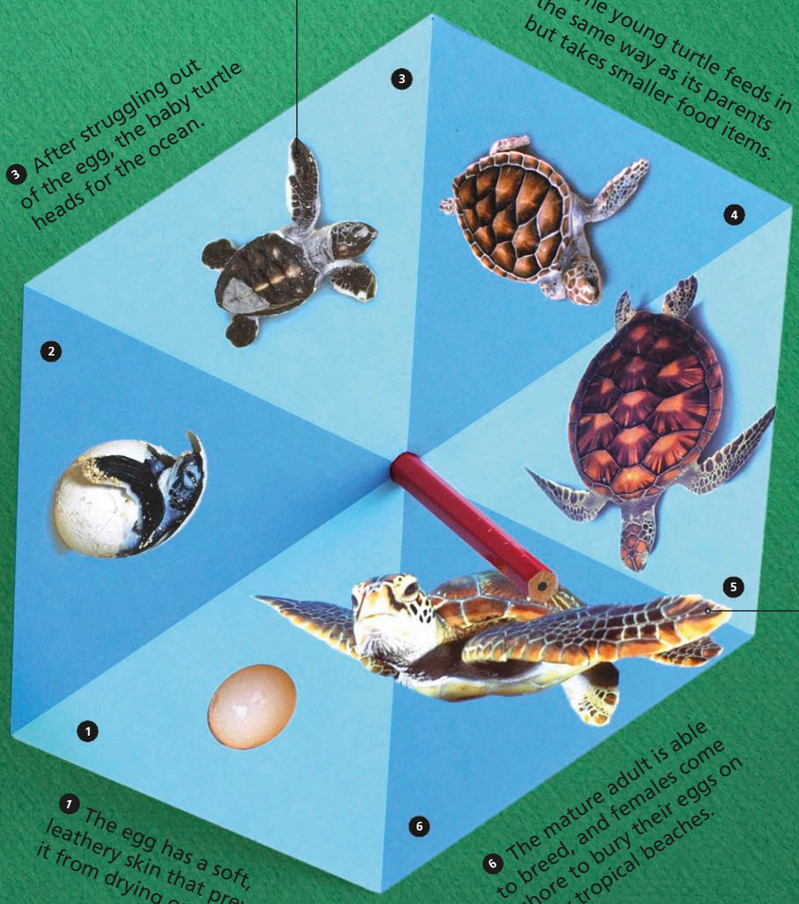
◀ BUTTERFLY

Butterflies, like many insects, have two quite different phases in their life cycle. They hatch as soft-bodied larvae that spend all their time eating and growing. Then they turn into winged adults, which do not grow and may not eat at all.



TURTLE ▶

Most reptiles, such as turtles, lizards, and snakes, lay eggs. When these hatch, the babies that crawl out are like miniature replicas of the adults. They live in exactly the same way and often eat the same foods.



Baby turtle has well-developed flippers when it hatches

❸ After struggling out of the egg, the baby turtle heads for the ocean.

❹ The young turtle feeds in the same way as its parents but takes smaller food items.

❺ Growing steadily as it feeds, the turtle does not go through any type of metamorphosis like an amphibian or insect.

Sea turtle's long flippers enable it to swim long distances to reach suitable breeding beaches

❷ An embryo develops inside the buried egg, which is abandoned by the mother but kept warm by the sun.

❶ The egg has a soft, leathery skin that prevents it from drying out.

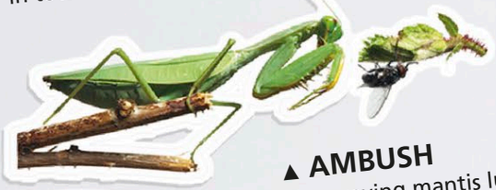
❻ The mature adult is able to breed, and females come ashore to bury their eggs on sandy tropical beaches.

ATTACK AND DEFENSE

Many animals are hunters that prey on other animals. Catching and killing fast-moving prey is hard, so over time hunters have evolved features and tactics to make the job easier. This has made survival harder for the animals that they hunt, so many have evolved defenses that make them difficult, or even dangerous, to catch.

◀ NIGHT HUNTER
Insect-eating bats target their prey using pulses of high-pitched sound. The sounds bounce off the victim, creating a sound image that enables a bat to hunt flying insects in total darkness.

DRIFTING TRAP ▶
The long tentacles of the box jellyfish are armed with thousands of tiny stinging cells. The animal simply drifts with the currents and devours any creature that is unlucky enough to come into contact with its tentacles.



▲ AMBUSH
The praying mantis lurks motionless on a plant, waiting for another insect to come within range. Then it shoots out its spiny front limbs to catch its victim and eats it alive.

◀ VENOM AND CLAWS
Many animals have venomous bites or stings that they can use to kill their prey and to defend themselves. A scorpion normally uses its claws to hunt and the sting on the end of its tail for defense.

◀ TEAMWORK
Lions are equipped with daggerlike teeth and long claws, but their main weapon is teamwork. They encircle their prey so there is no escape.

CONSTRICTOR ▼
A python coils around its prey, squeezing a little tighter every time the victim breathes out, until eventually it cannot breathe at all. A snake's lower jaws are loosely linked to its skull, so it can swallow its prey whole.

POISON GLANDS ▶

If attacked by a hunter, a toad defends itself by inflating its body with air and oozing poisons from its skin. This makes it hard to eat and also makes it taste unpleasant so its enemy is likely to leave it alone.

CAMOUFLAGE ▼

The best defense is to avoid being noticed at all. Camouflage makes animals hard to see against their background. This mountain hare turns white in winter to match the snow.

SPINES ▼

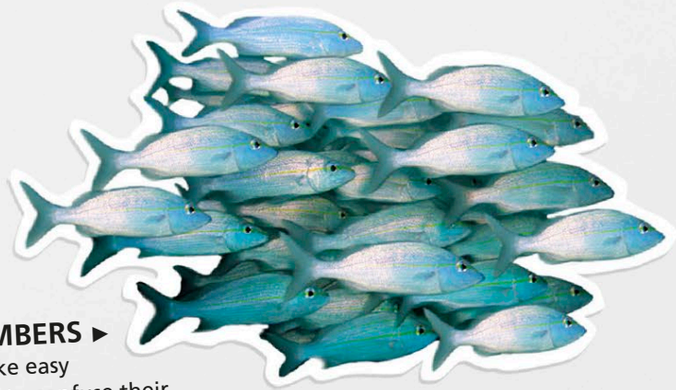
Some animals have defensive armor. Others, like this porcupine, bristle with long, sharp spines. This can make them almost impossible to attack and even dangerous to animals that try.

PLAYING DEAD ▼

Many hunters will eat only prey that they have killed themselves. Some animals like this opossum take advantage of this by "playing dead" if threatened. An opossum may keep up the pretense for six hours!

NOXIOUS SMELL ▼

Skunks are notorious for the vile-smelling fluid that they spray from scent glands under their tails if attacked. They can aim accurately for up to 7 ft (2 m), often targeting the faces of their enemies.



SAFETY IN NUMBERS ▶

Solitary animals make easy targets, so many try to confuse their enemies by living in dense shoals, flocks, or herds. By staying close together, this shoal looks like one big fish rather than lots of little ones.

Ball python

▲ PYTHONS

Most of the biggest snakes are pythons—powerful, nonvenomous reptiles that kill their prey by coiling around it and squeezing until it cannot breathe.

Much smaller than many pythons, this West African species is a burrowing snake that eats rodents

This is the snake's tail, which it uses as a fake head to deceive its enemies if threatened

Calabar ground python

COLUBRIDS ▼

Three-fifths of all snake species belong to the colubrid family. Most are harmless, but some, including the mangrove snake, have venomous fangs at the backs of their mouths.

Mangrove snake

Snakes shed their outer skin at least once a year, emerging with glossy scales and brighter colors

Grass snake

Corn snake

IGUANAS ▼

Iguanas are typical lizards—reptiles that usually have four legs, a long tail, and scaly skin. Most lizards eat small animals, but the green iguana is mainly vegetarian.

Green iguana

▼ VENOMOUS LIZARDS

The Gila monster is one of just two species of lizards with a venomous bite. Both live in deserts in Mexico and the United States.

Gila monster

CHAMELEONS ▶

Famous for their ability to change their skin color, chameleons are slow-moving lizards that hunt by shooting out their very long, sticky tongues to catch insects.

Jackson's chameleon

GECKOS ▼

Special hairs beneath the broad toes of many geckos act like suckers, enabling these active, agile lizards to climb up any surface, including glass, and even run across ceilings.

Madagascar day gecko

European glass lizard

REPTILES

Scaly, creeping, cold-blooded reptiles can seem sinister–especially venomous snakes and snapping crocodiles. Yet many reptiles are glossy, vividly colored creatures with fascinating habits. Most are hunters, but since they do not use any energy keeping warm, they do not need to eat much. Crocodiles often go for months without eating, and some big snakes can survive for a year on just one big meal.

The grass snake is an excellent swimmer. It ripples its body to move through water in search of frogs to eat

Sensing danger, this grass snake is "playing dead" in the hope that it will be ignored

The red-tailed racer's slender body is adapted for climbing

Red-tailed racer

LEGLESS LIZARDS ▸
Some lizards have no legs, so they look and behave like snakes. The European glass lizard has tiny vestiges of legs, showing that its ancestors were like normal lizards.

▾ TUATARA
Found only in New Zealand, the two species of tuatara are the only survivors of a group of reptiles that mostly died out 100 million years ago, during the age of dinosaurs.

Tuatara

This small turtle has a streamlined shell to help it glide through water

Slider terrapin

Hermann's tortoise

▲ TURTLES
Instantly recognizable by their shells, turtles and tortoises have existed since the days of the first dinosaurs. Tortoises are famously slow, but turtles can swim quite fast over long distances.

▾ COBRAS
Among the deadliest of venomous snakes, cobras are armed with a nerve poison that paralyzes their victims so they cannot breathe and they die from suffocation.

Albino monocled cobra

Rattlesnake

VIPERS ▸
Equipped with long poison fangs that hinge forward when they open their mouths, vipers such as rattlesnakes are extremely dangerous. Luckily, rattlesnakes rattle their tails as a warning.

American alligator

▲ CROCODILES
The most powerful of all reptiles, alligators and crododiles are ferocious predators that ambush, kill, and eat animals as big as zebras.

MOLLUSKS

Snails, clams, mussels, and even octopuses are all mollusks–soft-bodied animals that often have strong chalky shells. Some live on land, but most mollusks live under water or on tidal seashores. A snail or octopus can move about and use its sense organs to find food, but many aquatic mollusks, such as mussels, spend their adult lives in one place. They do not have obvious sense organs or even heads, and their bodies are encased within two shells that can be closed for protection.

❶ **Snail** Able to creep around on its muscular foot, a snail can squeeze its soft, boneless body into its coiled shell when it feels threatened.

❷ **Giant snail** A native of tropical Africa, the giant snail can be 12 in (30 cm) long. A gland at the front of the foot produces the slime that enables a snail to slide along.

❸ **Giant clam** The biggest of all mollusks, the giant clam can grow to more than 40 in (1 m) across. It finds a spot in a coral reef and, once there, stays in place for life.

❹ **Squid** Fast-swimming squid can catch fish with their tentacles, change color, and shoot through water backward using jet propulsion.

❺ **Slug** Basically snails without shells, slugs can live in places with few of the chalky minerals that other mollusks need to build up their shells as they grow larger.

❻ **Limpet** Able to clamp its strong shell to rocks, the limpet is well equipped to survive the rough and tumble of rocky seashores.

7 Octopus Like the cuttlefish and squid, an octopus is an intelligent animal with excellent eyesight. It uses the strong suckers on its eight long arms to catch crabs.

8 Whelk A type of sea snail, the whelk uses its acute sense of smell to track down dead animals in the water for food.

9 Scallop Like clams, scallops are two-shelled bivalves. By snapping their shells shut, they can shoot through the water when they need to escape danger.

10 Mussel All mussels attach themselves to rocks with strong threads and live by pumping food-rich water through their bodies.

11 Sea slug Many sea slugs have flamboyant frills. Bright colors act as a warning to predators to leave them alone.

12 Cuttlefish Unlike most mollusks, a cuttlefish has an internal shell. This can be filled with air to make it buoyant, so the cuttlefish can drift through the water after its prey.

SHELLS

The bodies of some creatures are protected by strong shells. They include all kinds of animals ranging from crabs to armadillos, but the most well known are marine mollusks such as winkles, cockles, and clams. These animals absorb chalky minerals from their food or seawater and turn them into beautiful, sculptured, often vividly colored "sea shells." These are sometimes lined with iridescent, gleaming mother-of-pearl.

❶ NAUTILUS

A relative of the octopuses, with big eyes and up to 90 tentacles, the nautilus can retreat into its pearl-lined shell for safety. The inner chambers of the shell act as flotation tanks.

❷ VENUS COMB MUREX

Named for its comblike appearance, this sea snail of the tropical Indian and Pacific Oceans has up to 100 sharp spines that protect it from predators such as shellfish-eating rays.

❸ PAPAL MITER

This is one of about 800 known species of miter shells, which all have a pointed form similar to the ceremonial hats worn by bishops and popes. The papal miter may be up to 6 in (15 cm) long.

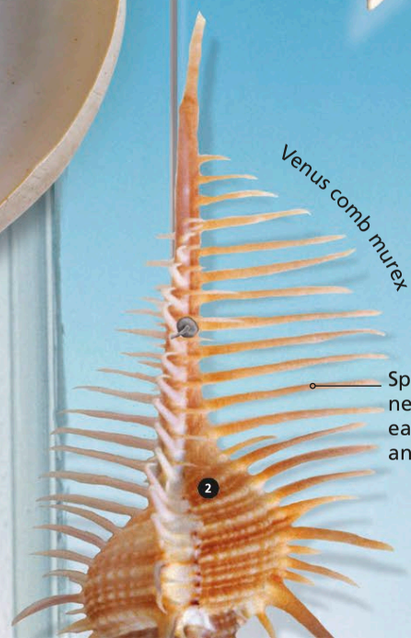
❹ CUBAN LAND SNAIL

Some land snails are brightly colored, too, but their colors are usually similar to those of the places where they live. Snails that have noticeably different colors are soon eaten by birds.

Cowrie shells are glossy where partly covered by the animal's body

A nautilus can adjust its buoyancy by pumping fluid in and out of gas-filled shell chambers

Cross-section of a nautilus shell



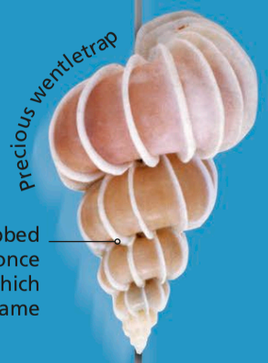
Venus comb murex

Spines are as sharp as needles and break off easily if they pierce another animal

Distorsio shells are found mainly in tropical waters

Common distorsio

Papal miter



Precious wentletrap

This delicately ribbed sea shell was once highly valued, which explains its name

❺ OYSTER SHELL

Most oysters have shells that are rough outside but pearly inside. Grains of sand that find their way into oyster shells are smothered with layers of shell material, turning them into pearls.

❻ SEA URCHIN TEST

Sea urchins belong to a group of animals called echinoderms. Their "shells" are covered with skin, so they are not true shells like those of mollusks. Known as tests, they are peppered with holes and small knobs where the spines were once attached.

❼ SPINY SAND COCKLE

Cockles and clams are mollusks with two shells, called bivalves. A cockle burrows into sand, often on coasts that dry out at low tide, but it can close its shells tightly to keep itself moist until the tide turns.

❽ MANUS ISLAND SNAIL

All snails have a shell that is coiled in a spiral, so the coil gets smaller toward the tip. As the snail grows, it adds shell material at the shell mouth, which gets broader all the time.

BIRDS

The only animals with feathers, birds are found in all parts of the world. Many have superb flying skills, with strong chest muscles to power their flapping wings. There is a dazzling diversity of species, from soaring albatrosses and flamboyant peacocks to flightless rheas and tiny hummingbirds.

▲ TAWNY EAGLE
Eagles are powerful hunters. They target their prey while soaring high overhead then swoop down to seize it in their talons. The tawny eagle is also notorious for stealing the victims of other birds of prey.

ZEBRA FINCH ▲
Like many birds, the zebra finch of Australia lives in large flocks that fly and feed together for safety. Its stout bill is adapted for splitting the tough skins of grass seeds to get at their nourishing kernels.

▲ RHEA
As tall as 5 ft (1.5 m), these large flightless birds roam the grassland of South America. They eat plants, nuts, seeds, and fruits as well as insects and small animals, such as lizards.

▲ ALBATROSS
The long, narrow wings of an albatross enable it to soar for hours on oceanic winds without moving a muscle. It feeds on marine animals, which it snatches from the ocean with its bill.

SNOWY OWL ►
Most owls hunt by night, but the snowy owl is active during the almost continuous daylight of the Arctic summer. It uses its acute hearing to locate small animals such as lemmings feeding beneath the snow.

◄ WOODPECKER
Woodpeckers use their powerful bills to carve out nesting holes in trees, and many also hack into soft wood to find insects. This green woodpecker catches ants with its extra-long tongue.

TOUCAN ►
The enormous bill of the toco toucan is much lighter than it looks, because it is a hollow shell of lightweight horny material supported by crisscrossing internal struts. The toucan uses it for display as well as feeding.

FLAMINGO ▲
Vast wading flocks of flamingos gather tiny animals and algae from warm lakes. Holding their extraordinary bills upside down in the shallows, they use their tongues to pump water through their sievelike bill fringes to trap food.

PEAFOWL ►
The female peafowl, or peahen, looks drab and colorless compared to the dazzling male peacock, with his amazing courtship display of fanned tail feathers.

EGGS

All female birds lay eggs. The young grow inside the eggs, which are kept warm by their parents. To hatch, they must chip their way through the eggshell. Some chicks, such as ducklings, can run and walk around soon after hatching, but other baby birds hatch at a much earlier stage in their development when they are naked, blind, and almost helpless.

❶ GREAT AUK
This beautiful egg is one of the last relics of a big flightless seabird that once lived in the north Atlantic and hunted fish like a penguin. Each pair laid just one egg, and the last-known pair was killed in 1844.

❷ GOLDEN EAGLE
A female golden eagle lays two eggs a few days apart. She keeps the first egg warm so it hatches earlier. This chick may be the only one to survive if food is hard to find.

❸ KING PENGUIN
King penguins breed in huge colonies on windswept rocky islands around Antarctica. Each female lays one egg, and both parents take turns keeping it warm by supporting it on their feet beneath their warm bellies.

❹ OSTRICH
The ostrich is the world's largest bird, and it lays the biggest eggs. Each one can weigh anything up to 4 lbs (1.9 kg)—the same weight as 27 chicken eggs.

❺ QUAIL
The quail lays a huge clutch of up to 18 eggs in a nest on the ground. Like many eggs, they have camouflage markings that make them harder to see. The female starts keeping them warm only after she lays the last one. This means they start developing at the same time, so they all hatch at once. The chicks are active as soon as they hatch, just like ostriches.

❻ SPARROWHAWK
In the 1960s, sparrowhawks suffered from poisoning by pesticides used in farming. The poisons thinned their eggshells, so they broke when the birds tried to keep them warm. Most of these pesticides are now banned.

❼ CUCKOO

Cuckoos lay single eggs in the nests of other birds, and their color varies to match the host bird's eggs. When the cuckoo hatches, it heaves the other eggs out so it can eat all the food its foster parents collect.

❽ KIWI

A kiwi is 20 times smaller than an emu, yet their eggs are almost the same size. This means that the egg is huge compared to the kiwi that lays it, at up to a quarter of her weight. That's like a human mother giving birth to a three-year-old child.

❾ COMMON SANDPIPER

Sandpipers are shorebirds that lay their eggs in shallow scrapes on the ground near the water. Their pointed shape allows them to be pushed together in a tight clutch to take up less space. The eggs are camouflaged by speckled patterns, and can be hard to see—but if you do find any birds' eggs, remember it is illegal to collect or disturb them.

❿ HUMMINGBIRD

Hummingbirds lay the smallest of all birds' eggs. The bee hummingbird's egg is the size of a pea, because the bird itself is no bigger than a large moth. This ruby-throated hummingbird's egg is bigger but still tiny compared to the ostrich egg.

⓫ CHICKEN

The egg that everybody recognizes is laid by the domestic chicken. We eat 1.1 trillion of these eggs every year.

MOVEMENT

The feature that makes animals so different from other living things is their ability to move. Some do not move much–a sea anemone, for example, is sedentary (remains in one place) and catches anything that touches its tentacles. Most animals, however, travel to look for food, find breeding partners, or escape from their enemies. They slither, crawl, walk, hop, run, swim, and fly, sometimes at incredible speed. Some have evolved other amazing ways of getting around, like the insects and spiders that walk on water and the extraordinary sidewinding rattlesnakes.

❶ GIBBON
Although gibbons can walk well, they usually move through the forest by using their long, powerful arms to swing from the trees. They hurl themselves from branch to branch with astonishing speed, agility, and elegance.

❷ SNAKE
A typical snake slips along by curving its flexible body around plants and stones and pushing the curves toward its tail. Sidewinders like this desert viper have a more baffling method, looping sideways over the sand like rolling springs.

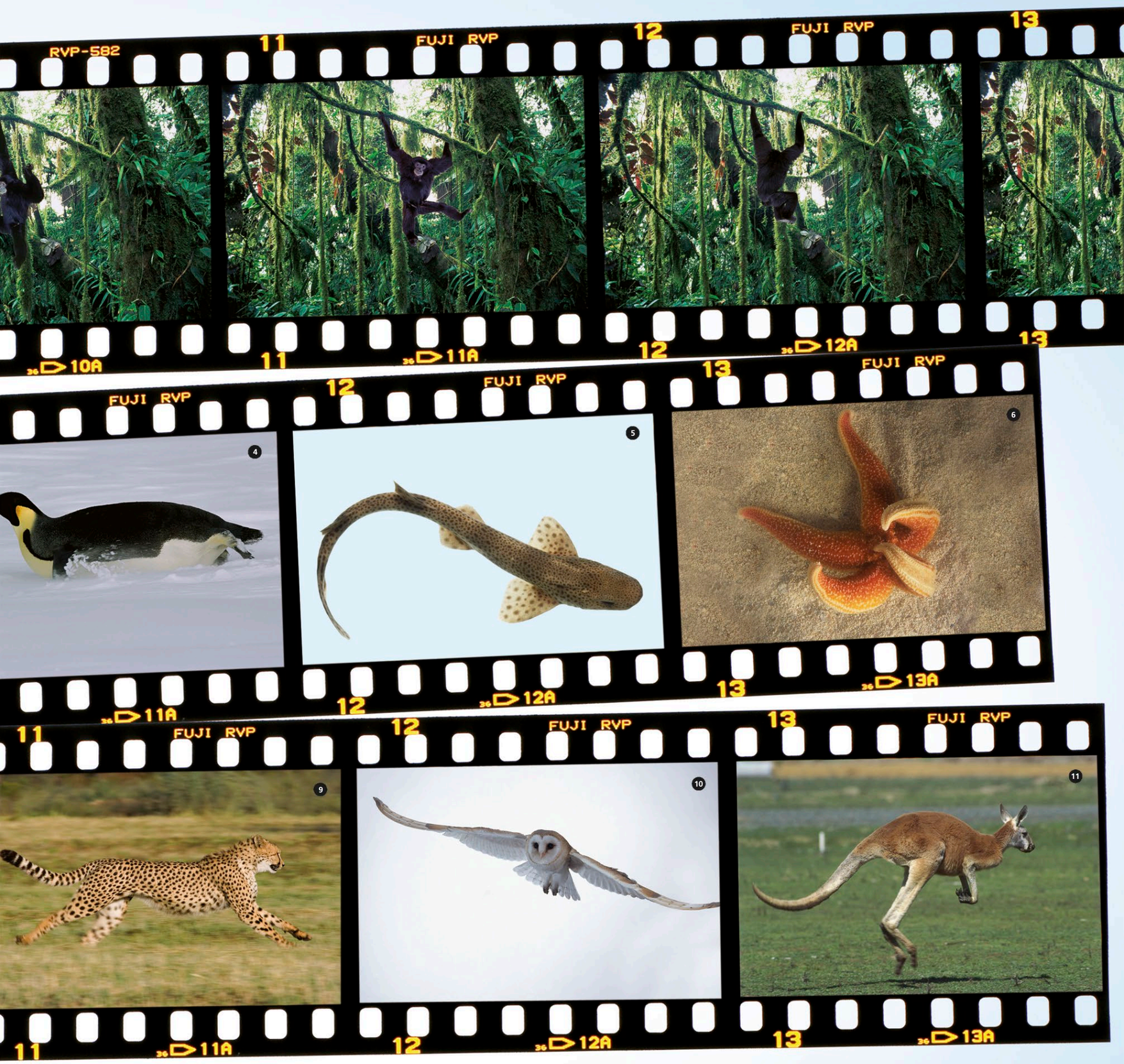
❸ OCTOPUS
An octopus normally hauls itself over the seabed using its long, elastic arms. But it can shoot away from danger by jet propulsion, drawing water into its body and blasting it out at high pressure. Cuttlefish and squid do the same.

❹ PENGUIN
All penguins are superb swimmers, using their wings to "fly" through the water, but they walk clumsily. On snowy slopes, they often prefer to toboggan on their well-padded bellies, pushing themselves along with their stoutly clawed feet.

❺ FISH
Most fish have flexible bodies that allow them to move through the water using their fins for stability and to control their direction. Some fish, such as tunas, propel themselves at high speed using just their tails.

❻ STARFISH
A starfish can curl its arms, but it actually creeps over the seabed using hundreds of tiny "tube feet" on its underside. Each tube foot is pumped full of water and is extended and moved by changes in water pressure.

❼ SNAIL
The muscles in a snail's foot contract and expand to create a rippling movement that pushes the snail forward. Glands in the foot produce a slimy mucus to make the track slippery. The slime also protects the snail from debris.



❽ WATER STRIDER

The water molecules at the surface of a pool cling together to form an elastic film, strong enough to support tiny animals like this water strider. Its special brush-tipped feet just dimple the surface, so it can skate around without sinking.

❾ CHEETAH

The fastest of all land animals, a cheetah can run at an astonishing 60 mph (95 km/h). It achieves this by flexing its back to extend its stride as it bounds forward on its long legs, but it can keep this pace up for only about 40 seconds.

❿ BARN OWL

Birds are the masters of the air. Most, like this barn owl, use their powerful feathered wings to drive themselves forward. Others can travel long distances by soaring on rising air currents like gliders, without beating their wings at all.

⓫ KANGAROO

A leaping kangaroo uses the elastic tendons in the backs of its legs like the springs of a pogo stick. Every time it lands on its long feet, the tendons stretch like rubber bands then spring back again to catapult the kangaroo forward.

LIVING TOGETHER

Animals and plants often rely on other living things for survival. Food, shelter, and pollination are some of the clearest examples of this. However, some animals and plants have much closer relationships. They can be partners, providing things like food or protection for each other. Some tag along with others without providing anything in return. Many do worse, latching on to other organisms as parasites, which can harm or even kill their often helpless hosts.

The microscopic algae that live in partnership with this coral provide its vivid color

1

2

This long, tubular flower is a perfect fit for the long bill of the sword-billed hummingbird

3

Ants protect the aphids from their enemies in exchange for sweet, syrupy honeydew

4

This cuckoo chick has outgrown both the host bird and its nest, but it still cries out for food

A strangler vine uses a tree for support but eventually kills it by competing for food and light

5

An impala welcomes the attention of a red-billed oxpecker searching for tasty parasites

A remora clings to a shark's skin using a special sucker on the back of its head

❶ CORAL
Corals trap prey in their stinging tentacles. They pass some of the nutrients from their victims to tiny algae living in their tissues. These use the sun's energy to make sugar, and they pass some of this food back to the corals.

❷ HUMMINGBIRD
Hummingbirds gather flower nectar, and in the process they carry pollen from flower to flower. Some plants have evolved flowers that match the bills of particular hummingbird species, to encourage the birds to visit them and deliver their pollen efficiently.

❸ ANTS AND APHIDS
Aphids are tiny insects that feed on sugary plant sap. They must eat a lot of it to get enough protein, and they excrete the excess sugar as drops of sweet honeydew. Ants love to drink this, so they "farm" the aphids, protecting them from predators, ensuring a constant supply.

❹ CUCKOO
Cuckoos are "brood parasites"—they lay their eggs in the nests of other birds. Each young cuckoo hatches quickly and destroys any other eggs in the nest, so it can eat all the food brought by its foster parents. It soon outgrows its hosts, who often do not seem to notice its massive size.

❺ STRANGLER VINE
Some slender rain forest plants, such as figs, grow by encircling a tree and slowly killing it—a process that can take up to 150 years. They steal the tree's nutrients, and eventually the tree dies and decays, leaving the fig plant standing alone.

❻ OXPECKER
Hoofed grazing animals, such as impalas, are often plagued by tiny bloodsuckers, such as ticks, that they cannot remove by scratching. In Africa, stout-billed birds called oxpeckers do the job for them by picking the parasites off their skin and eating them.

❼ REMORA
Predatory sharks have very sharp teeth that cut their prey to shreds. The scraps are eagerly devoured by fish called remoras, which travel with the sharks by clinging to their skin. They do their hosts no harm, and the sharks seem to ignore them.

MAMMALS

Mammals are warm-blooded creatures that feed their babies on milk until the young are able to eat solid food. Most are furry or hairy, unlike all other vertebrates (animals with backbones). Many eat plants, while others prey on other animals. Some, like humans, eat both plants and meat.

ECHIDNA ►
The echidna and the equally strange platypus are the only mammals that lay eggs. A baby echidna lives on milk produced by its mother for up to six months. The mother eats food such as earthworms, which she digs from the ground with her long snout.

▲ MOUSE
Nearly half of all mammal species are rodents—a group that includes mice, rats, beavers, porcupines, and squirrels. The house mouse is the only mammal, aside from humans, to live on every continent.

◄ ELEPHANT
Elephants use their sensitive trunks to gather coarse vegetation, which they grind to pulp with their massive teeth. They are the biggest land animals and are very intelligent.

▲ BAT
Bats are mammals that can fly. Some eat fruit, but most species, like this long-eared bat, catch insects. They are nocturnal (active at night) and locate prey in the dark by emitting high-pitched clicks and listening for echoes from their target.

KANGAROO ►
Marsupials such as kangaroos give birth to tiny young that are only half formed. The newborn crawls into a pouch on its mother's belly to drink milk and grow into a fully developed baby kangaroo, or joey.

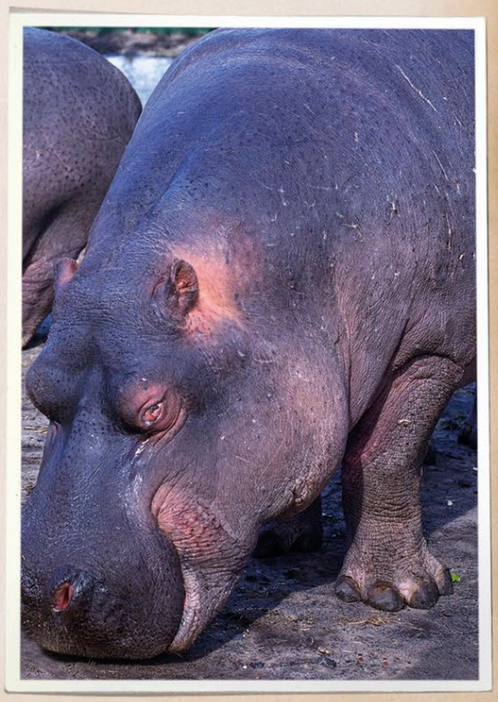
◂ TIGER
Powerful hunters like the tiger eat other mammals and birds. They have long, daggerlike canine teeth for killing their prey and scissorlike cheek teeth for slicing through hide and meat.

▲ MOLE
Moles are specially adapted to their underground environment. They have strong claws for digging and very sensitive whiskers, which compensate for their poor eyesight.

▲ KILLER WHALE
Whales and dolphins, like this killer whale, live in the ocean, swimming with up-and-down movements of their powerful tails. They come to the surface to breathe air.

◂ GORILLA
Our closest relatives among the mammals are apes like the gorilla—a plant eater that lives in the rain forests of tropical Africa.

HIPPOPOTAMUS ▸
The hippopotamus spends most of its time wallowing in rivers and lakes. The massively built plant eater has the largest mouth of any land mammal.



SLEEP

Animals sleep to save energy, rest their muscles, and allow their brains to process the information that they pick up while awake. Some hunting animals sleep a lot, because they devote only a few hours each day to looking for food. Animals that are hunted spend much more of their time awake and alert.

❶ **Bats** sleep for about 20 hours a day, often in large colonies.

❷ **Two-toed sloths** are awake for only four hours a day. Like bats, they can cling to branches with their claws while fast asleep.

❸ **Gorillas** like to have about 12 hours of sleep a day.

❹ **Horses** need just three hours of sleep a day.

❺ **Elephants** stand up for two of the four hours a day they sleep. They have to lie down for the dreaming stage, when their muscles are too relaxed for them to stay on their feet. Large plant-eating animals tend to get less sleep than smaller animals, because they have to spend so much time looking for food and eating.

❻ **Seals** often sleep on rocks and beaches, but they can also sleep floating upright at sea, or even under water, surfacing to breathe without waking up.

❼ **Wolves** may sleep for up to 14 hours a day, especially if they have had a big meal after a successful hunt.

❽ **Pigs** need eight hours of sleep a day, just like adult humans.

❾ **Bears** also clock up about eight hours of sleep a day.

❿ **Tigers** sleep for up to 16 hours, since they can catch all the food they need within a very short time.

⓫ **Sheep** are descended from wild animals that needed to stay awake to escape predators, so they sleep for less than four hours a day.

⓬ **Kinkajous** are raccoonlike animals that forage for food at night and sleep all day for about 12 hours.

⓭ **Armadillos** sleep for 18 hours a day, curled up in their burrows.

⓮ **Human babies** need 15 hours of sleep a day. We sleep less as we get older, so adults sleep for an average of eight hours, and elderly people for less than six hours.

⓯ **Echidnas** are egg-laying mammals that sleep for about 14 hours a day. Scientists believe they do not have phases of dream sleep like other mammals.

⓰ **Red foxes** sleep for about 10 hours, mostly during the day. Like many hunters, they are more active at night when they track their prey using their sensitive noses and ears.

Horses can sleep standing up without toppling over because their legs lock in place

Dogs have similar sleep patterns to humans

22 **Chinchillas** sleep in burrows for about 13 hours a day, high in the mountains of South America.

23 **Rabbits** sleep for about eight hours, mainly during the day. They prefer to feed at night when they are not so vulnerable to predators.

24 **Chimpanzees** normally sleep for 10 hours a day, but baby chimps sleep for longer.

25 **Baby gorillas** need more sleep than their parents and may sleep or doze for more than 15 hours.

26 **Hedgehogs** usually sleep for 10 hours during the day. In winter, they hibernate (spend the cold months in a sleeplike, inactive state).

17 **Koalas** eat tough eucalyptus leaves that are hard to digest and provide little energy, so they spend about 15 hours a day sleeping and another five hours dozing.

18 **Dogs** sleep for 10 hours a day.

19 **Red pandas**, which are like bamboo-eating raccoons, sleep for about 11 hours a day.

20 **Cats** often sleep for 15 hours a day. Wild cats are most active during the night.

21 **Lions** sleep for at least 13 hours. While they sleep, other animals feed near them without risking attack.

Gharial crocodile

Crocodile teeth are all the same shape and can be replaced by new ones more than once

Gannet

CROCODILE ▲

One of the closest living relatives of the dinosaurs, crocodiles have long jaws studded with many sharp-pointed teeth for seizing their prey. The fish-eating gharial of Indian rivers may have more than 100 teeth.

Merganser

Tawny owl

Mallard

Broad skull houses big sensitive ears and huge eyes

Blackbird

Long bill of a curlew allows it to probe deeply into soft mud to catch worms

Curlew

Bony jaws support the bird's horny, lightweight bill

Amazon parrot

Hamster

Thin cranium is just strong enough to protect the brain

Hedgehog

Rabbit

Frog

PARROT ▶

All birds have thin, light skulls, which makes flying easier. Their beaks or bills are much lighter than toothed jaws. They are not built for chewing, yet the bills of some parrots are strong enough to crack nuts.

FROG ▶

The skull of a frog is broad, providing plenty of room for its large eyes and giving it an extremely wide mouth. This allows it to swallow its prey whole, so it does not need a set of teeth for chewing.

Armadillo

Badger

Collie dog

Deep ridge on back of skull anchors massive muscles attached to jaw

Lion

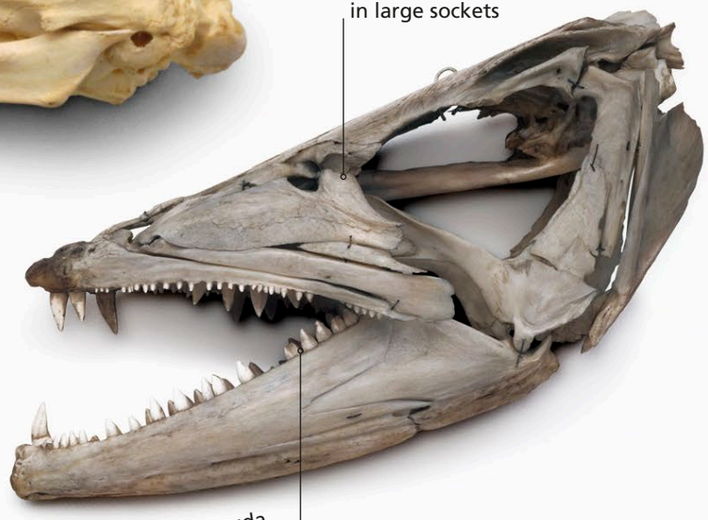
◀ LION

Like all cats, the lion is a dedicated hunter. It has short, powerful jaws with huge stabbing canine teeth at the front and meat-slicing carnassials at the back.

Anteater

Anteaters have long jaws and extremely long tongues but no teeth at all

BARRACUDA ▸
Fish have quite strong skulls, but the various parts are not fused together like those of mammals. The jaws of many fish are separate from the brain case but attached by bones that allow them to be thrust forward to seize prey.



The big eyes of this powerful, fast-swimming predator are contained in large sockets

Barracuda

Massive jaws are armed with needle-sharp teeth for a secure grip on prey

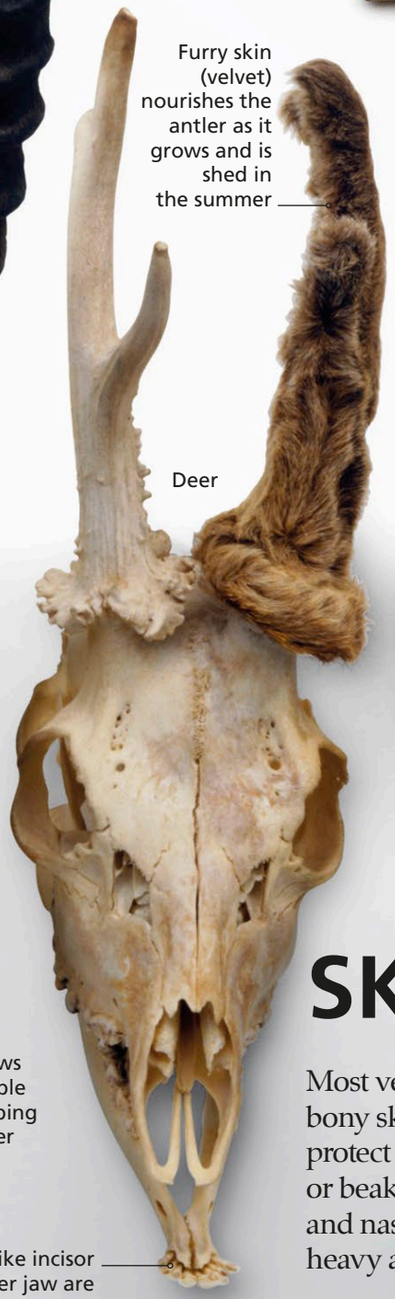
▼ ANTELOPE
Some animals, such as antelope and cattle, have massive horns on their heads for defense and fighting rivals. Male deer grow antlers, which they use to impress females and fight each other, but these antlers fall off at the end of the mating season. Each male grows a new pair every year.

Strong bony cores are sheathed with tough outer layers of ridged horn

Antelope

Long snout allows antelope to nibble grass while keeping watch for danger

Sharp, bladelike incisor teeth on lower jaw are ideal for cropping grass and gathering leaves



Furry skin (velvet) nourishes the antler as it grows and is shed in the summer

Deer

▼ BABOON
Close relatives of humans, baboons have similar skulls but longer jaws and bigger back teeth. This is because they eat large quantities of grass, which requires a lot of chewing. They also have long, sharp canines, which they use to kill animals for food and to fight among themselves.

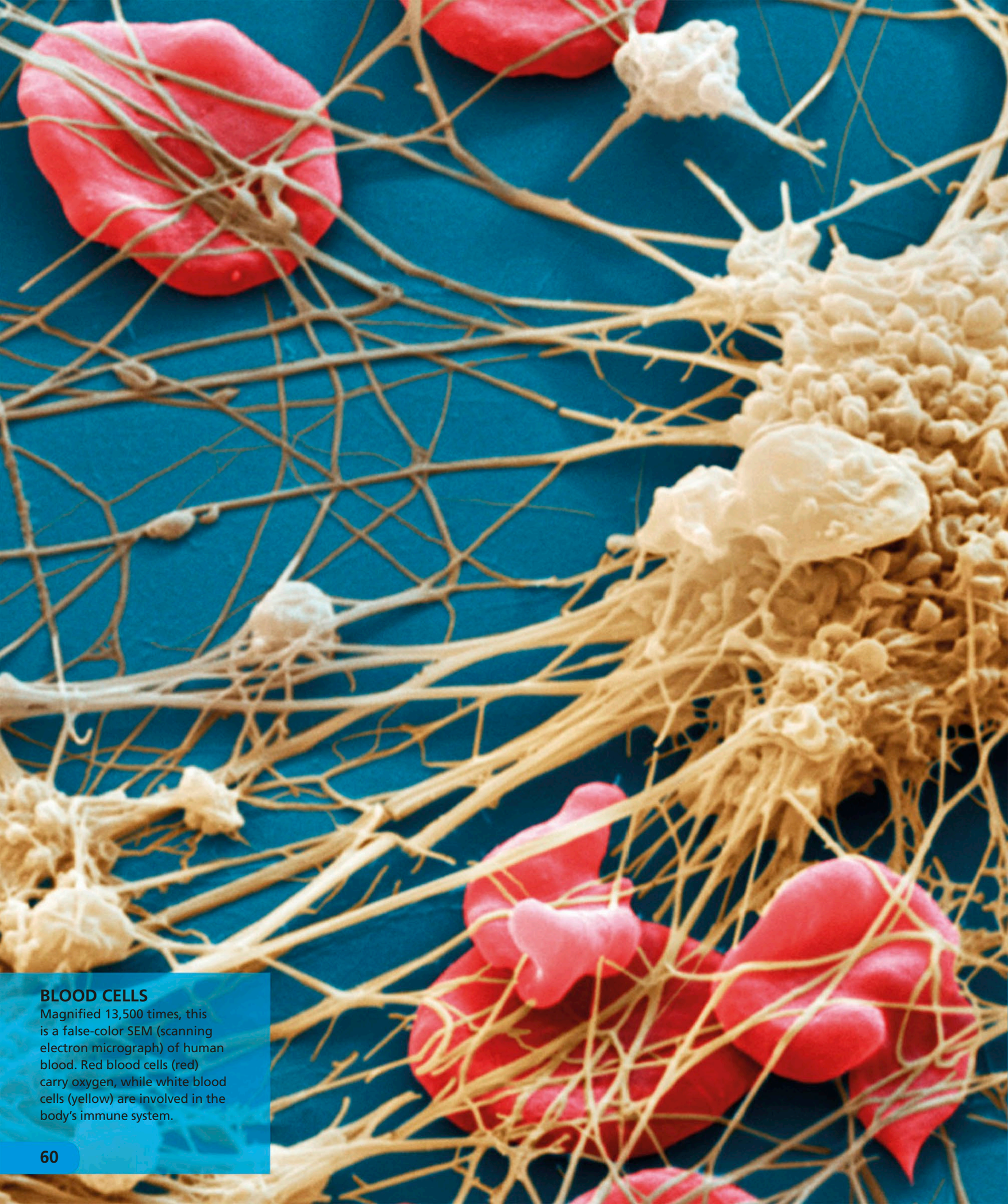
Baboon

Eye sockets at front of skull allow the baboon to see things in three dimensions

Nasal cavity contains thin scroll-like bones, which support the membranes that detect scent

SKULLS

Most vertebrates (animals with backbones) have strong bony skulls. They are made up of cranial bones that protect their brains, jaw bones that support their teeth or beaks, and face bones that contain their eye sockets and nasal cavities. The whole structure can be quite heavy and is supported by strong neck muscles.

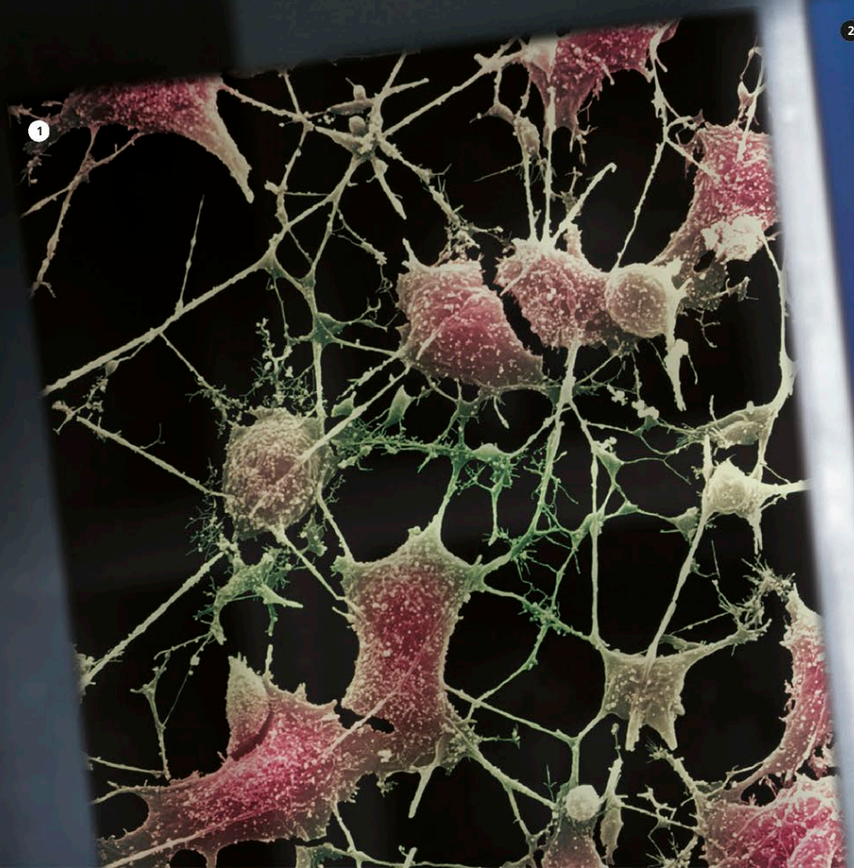


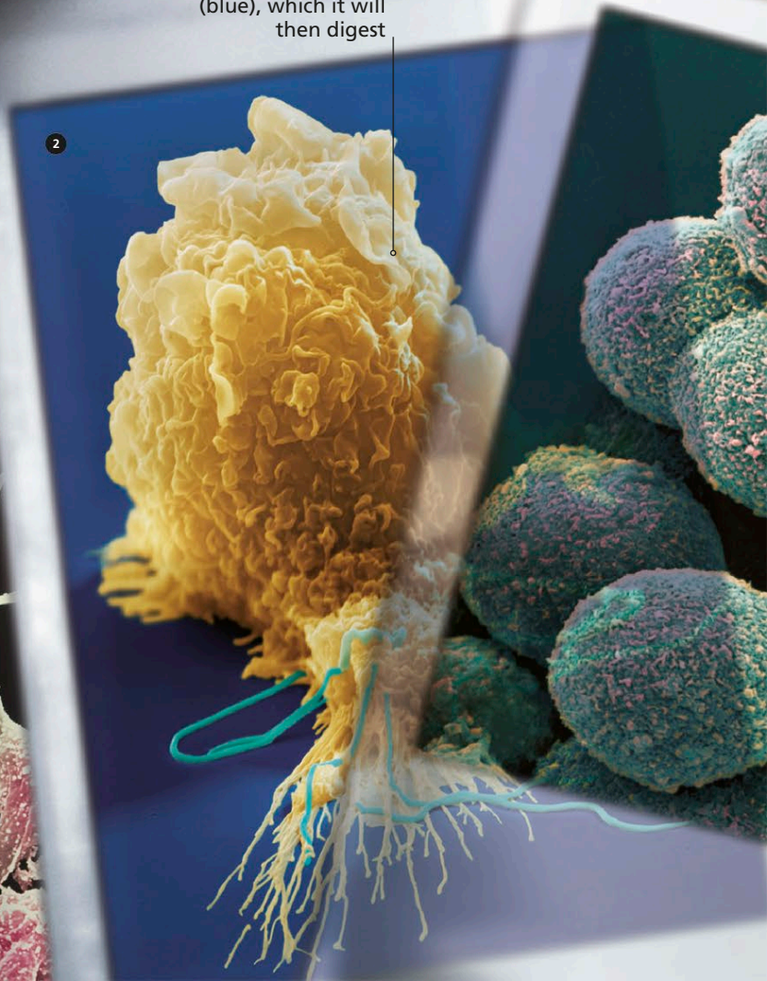
BLOOD CELLS
Magnified 13,500 times, this is a false-color SEM (scanning electron micrograph) of human blood. Red blood cells (red) carry oxygen, while white blood cells (yellow) are involved in the body's immune system.

Human body

CELLS

The body is constructed from trillions of tiny living units, known as cells. There are more than 200 different types of cells–and each has its own shape, size, and specific job to do. Typically, cells of the same type work together in units called tissues. Each individual cell is surrounded by a thin membrane that regulates the movement of nutrients and other substances in and out of the cell. Cells multiply by continually dividing into two identical "offspring." This division allows the body to grow and to replace cells that are damaged or worn out.





A macrophage "reaches out" to capture bacteria (blue), which it will then digest

❶ NERVE CELLS

Found in the brain, spinal cord, and nerves, nerve cells, or neurons, carry and process high-speed electrical signals, called nerve impulses. These impulses coordinate body processes and enable us to feel, think, and move.

❷ WHITE BLOOD CELLS

Circulating in blood, and in a clear fluid known as lymph, white blood cells help defend the body against disease. The cells include macrophages and neutrophils, which eat bacteria and other germs, and also lymphocytes, which release germ-disabling antibodies.

❸ EPITHELIAL CELLS

Tightly packed together, these cells provide a barrier to stop harmful chemicals and germs from reaching body tissues. They cover the body, forming the outer layer of skin, and line hollow organs such as the stomach, lungs, and bladder.

❹ BONE CELLS

Osteocytes are bone cells that help keep the bone in good condition. At first, they lay down bone but later become stranded within a bony space. They keep in touch through tiny threads and pick up supplies from nearby blood vessels.

❺ LIVER CELLS

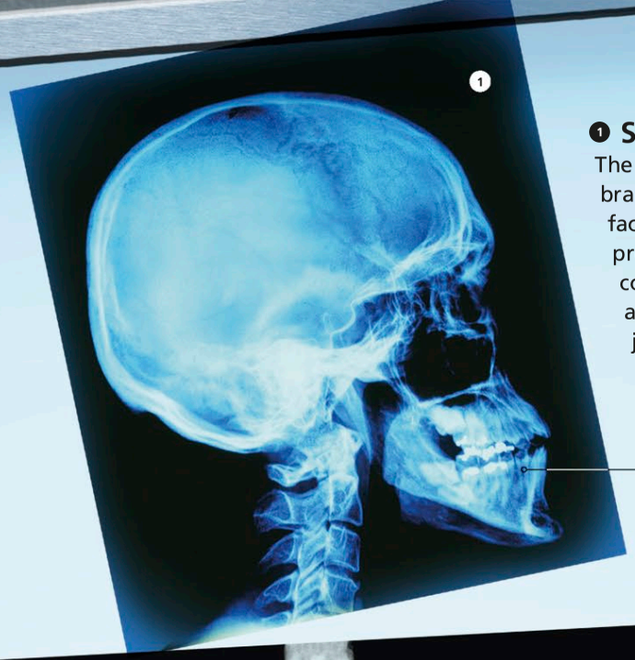
Also known as hepatocytes, liver cells enable the liver to perform many hundreds of roles to control blood composition and keep the body stable. These include processing and storing nutrients (foods) and removing poisons.

❻ FAT CELLS

As their name suggests, fat cells specialize in storing fat. They group together to form adipose tissue, which serves as an energy store, cushions organs such as the kidneys, and insulates the body under the skin.

SKELETON

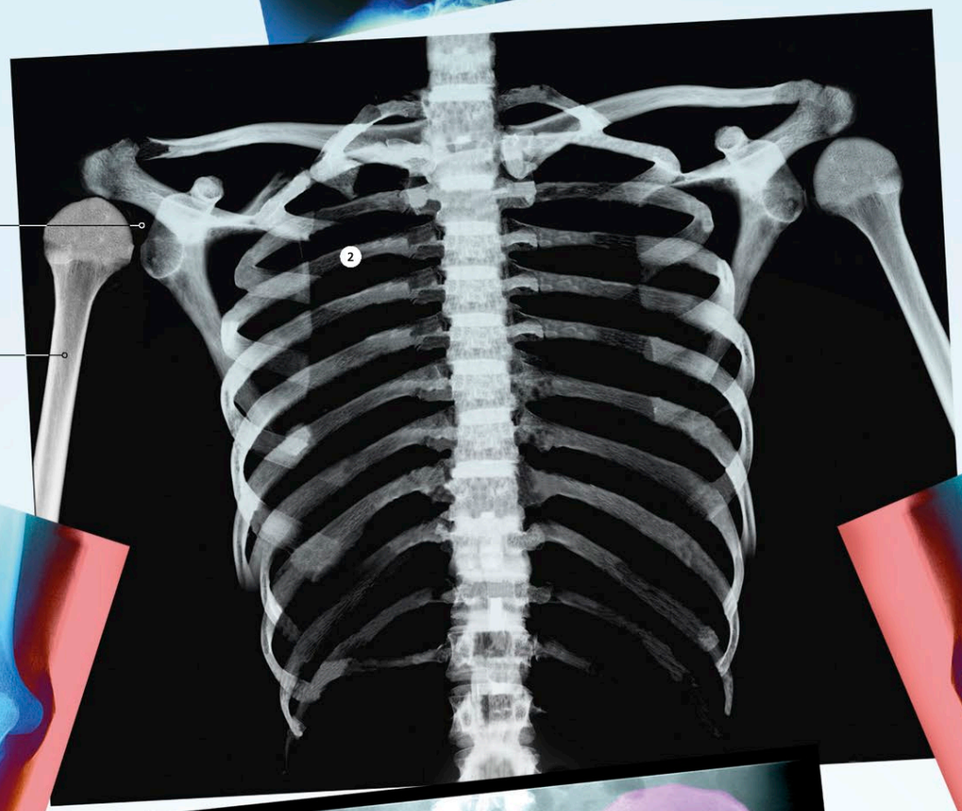
Constructed from 206 bones, the human skeleton is a strong, flexible framework that supports and shapes the body and produces movement when pulled by muscles. The skeleton also protects soft, internal organs, such as the brain and lungs. Bones, which make up 20 percent of the body's mass, are connected to each other at joints and are held together by strong straps of tissue called ligaments.



❶ SKULL

The bones in the skull protect the brain, provide a framework for the face, and anchor the muscles that produce facial expressions. The skull consists of 22 bones, 21 of which are locked together by immovable joints called sutures. Only the lower jaw (mandible) can move.

Mandible moves to open the mouth for eating, breathing, and speaking



❷ CHEST

The bones of the chest (thorax) consist of the sternum (breastbone), the ribs, and part of the backbone. Together, they form a protective "cage" that protects the lungs and the heart.

Shoulder joint is the most flexible joint in the body

Humerus

❹ ELBOW

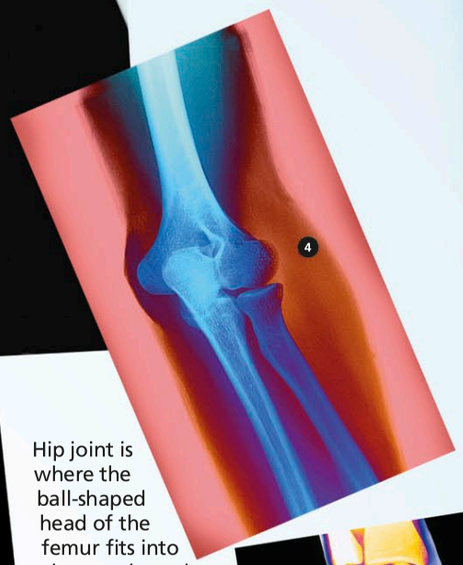
The bones of the upper arm and forearm meet at the elbow. This joint acts like a door hinge allowing the arm to bend or straighten. The forearm bones can rotate at the elbow, enabling the palm of the hand to face upward or downward.

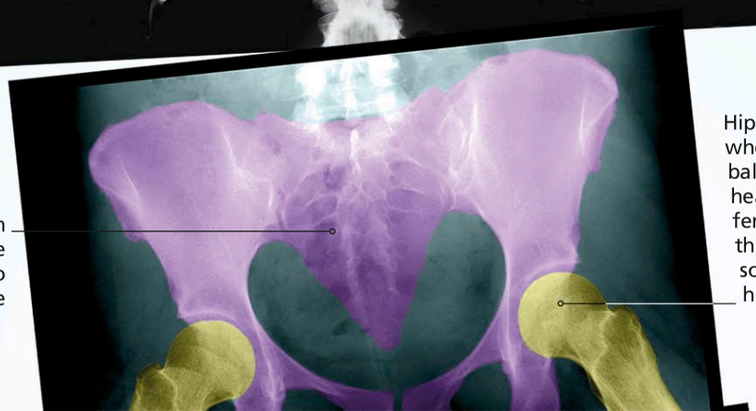
❸ FOREARM

The forearm is made up of two parallel bones—the ulna and the radius. The ulna curves around the humerus to form the elbow's point, while the radius forms a joint with the carpals (wrist bones).

Radius is the outer bone of the forearm

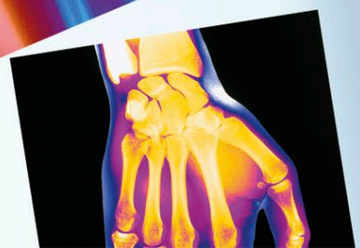
Ulna is the inner bone of the forearm

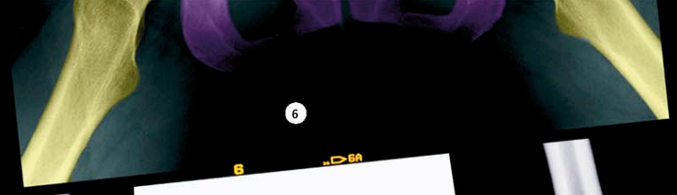


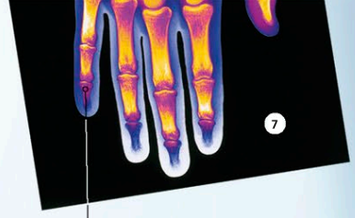


Sacrum anchors the backbone to the pelvic girdle

Hip joint is where the ball-shaped head of the femur fits into the cup-shaped socket in the hip bone

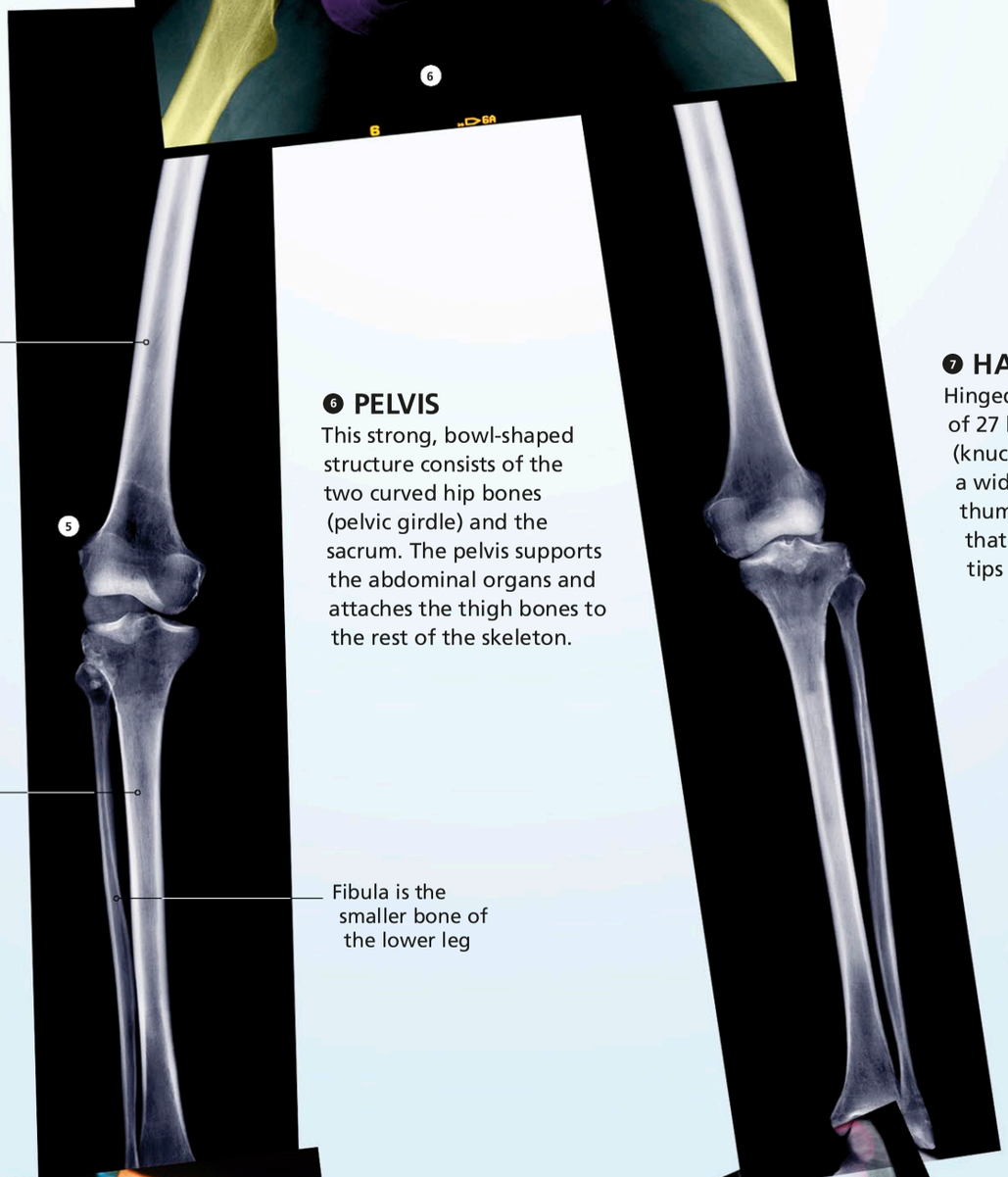






Phalanges are the 14 slender bones that form the fingers and thumb

Femur (thigh bone) is the longest bone in the body



❺ KNEE

The knee joint between the femur (thigh bone) and tibia (shin bone) is the strongest and most complex joint in the body. This hinge joint allows the leg to bend or straighten and supports the body's weight during activities such as running, jumping, or kicking.

❻ PELVIS

This strong, bowl-shaped structure consists of the two curved hip bones (pelvic girdle) and the sacrum. The pelvis supports the abdominal organs and attaches the thigh bones to the rest of the skeleton.

❼ HAND

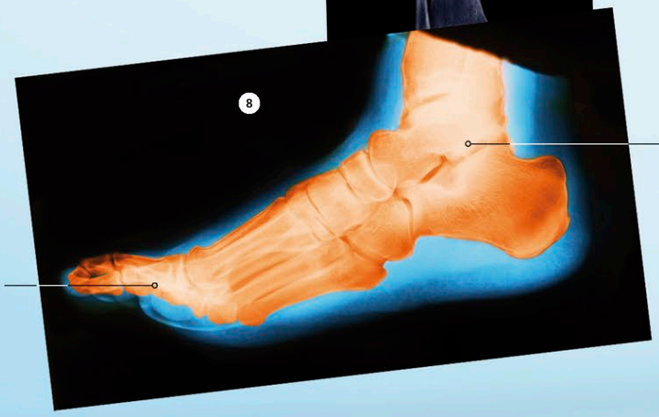
Hinged at the wrist, the hand consists of 27 bones and many movable joints (knuckles), which enable it to perform a wide range of tasks. The human thumb is opposable, which means that it can be rotated to touch the tips of each of the other fingers.

Tibia (shin bone) forms joints with the femur and ankle bones

Fibula is the smaller bone of the lower leg

❽ FOOT

Each foot consists of the ankle, sole, and toe bones, which support and move the body's weight. These bones also provide a flexible platform that pushes the body off the ground during movement and absorbs the shock on landing.



Tarsals are the seven bones that form the ankle, heel, and part of the arch of the foot

Phalanges are the 14 slender bones that form the toes

Metatarsals are the five long bones that connect the toes to the middle part of the foot

❾ TOES

The phalanges of the toes are much shorter and less flexible than those of the fingers. The phalanges enable the body to stay upright and to stand on tiptoe. They also help to propel the body forward during movement.

MUSCLES

Every body movement–whether it's a leap in the air, a wink of the eye, a rumbling stomach, or a rapid heartbeat–is produced by muscles. Skeletal muscles are attached to bones of the skeleton, which they pull to move us around. Smooth muscle moves food along the intestine. Cardiac muscle keeps the heart pumping. All muscles are made of cells called fibers that contract (get shorter) to produce a pulling force.

❶ SKELETAL MUSCLE

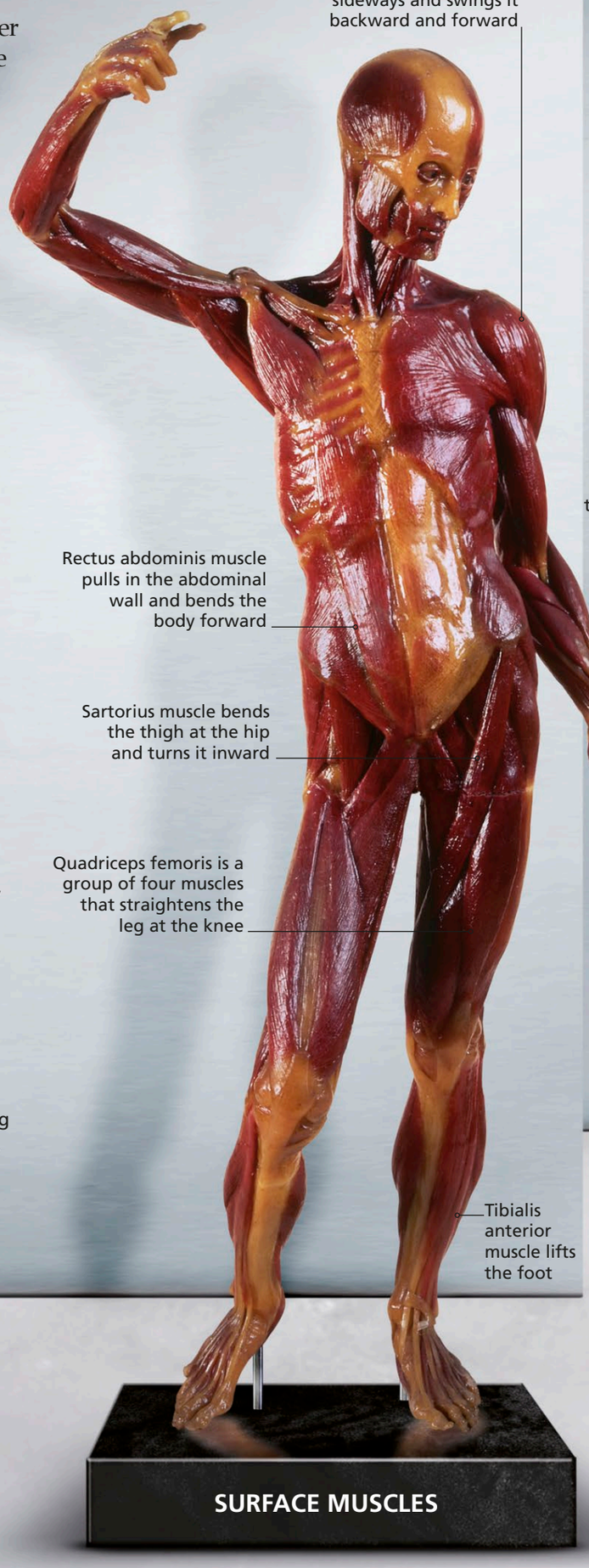
Long, cylindrical muscle fibers run in parallel and can reach up to 1 ft (30 cm) in length. They are bundled together to form muscles that are attached to bones by strong cords called tendons. Skeletal muscles move the body when instructed by the nervous system.

❷ SMOOTH MUSCLE

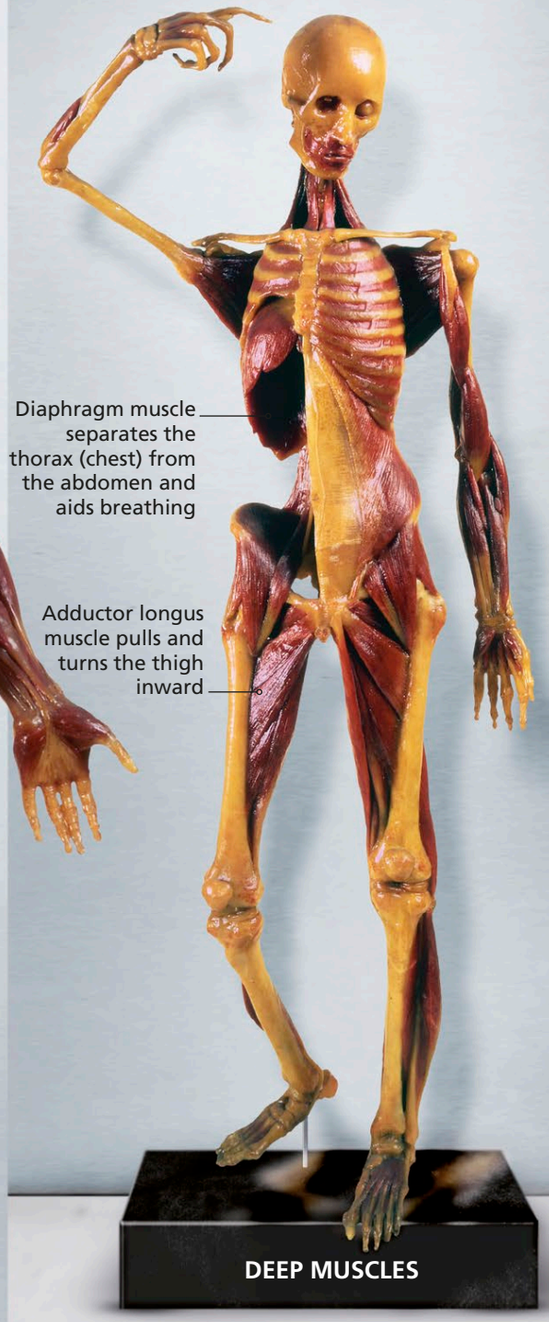
Tightly packed into layered sheets, smooth muscle fibers are found in the walls of hollow organs, such as the small intestine, along which they push food, and the bladder, from which they expel urine. Smooth muscle contracts slowly and cannot be controlled voluntarily.

❸ CARDIAC MUSCLE

Found solely in the wall of the heart, cardiac muscle fibers form a branching network that contracts automatically, without stopping or tiring, to pump blood around the body. Stimulation by the nervous system increases or decreases heart rate according to the body's demands.



SURFACE MUSCLES

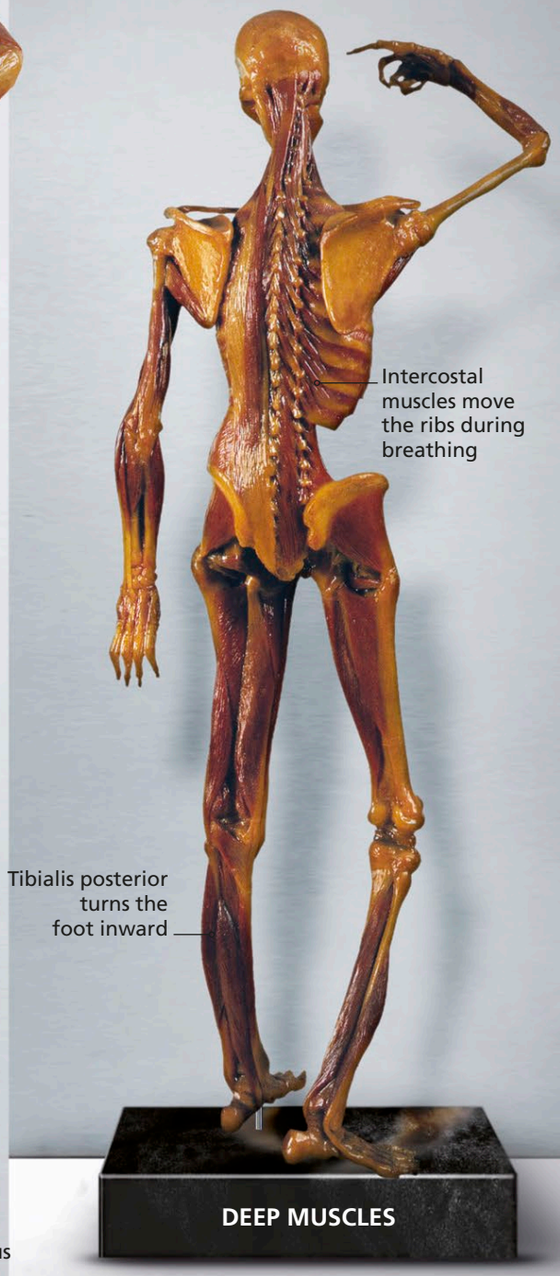


DEEP MUSCLES

FRONT MUSCLES

Skeletal muscles are arranged in overlapping layers, with surface muscles covering those deeper down. Muscles at the front of the body produce facial expressions, move the head forward and to the side, move the arms forward and bend them at the elbow, bend the body forward and to the side, bend the legs at the hip, straighten the knees, and lift the feet upward.

SURFACE MUSCLES



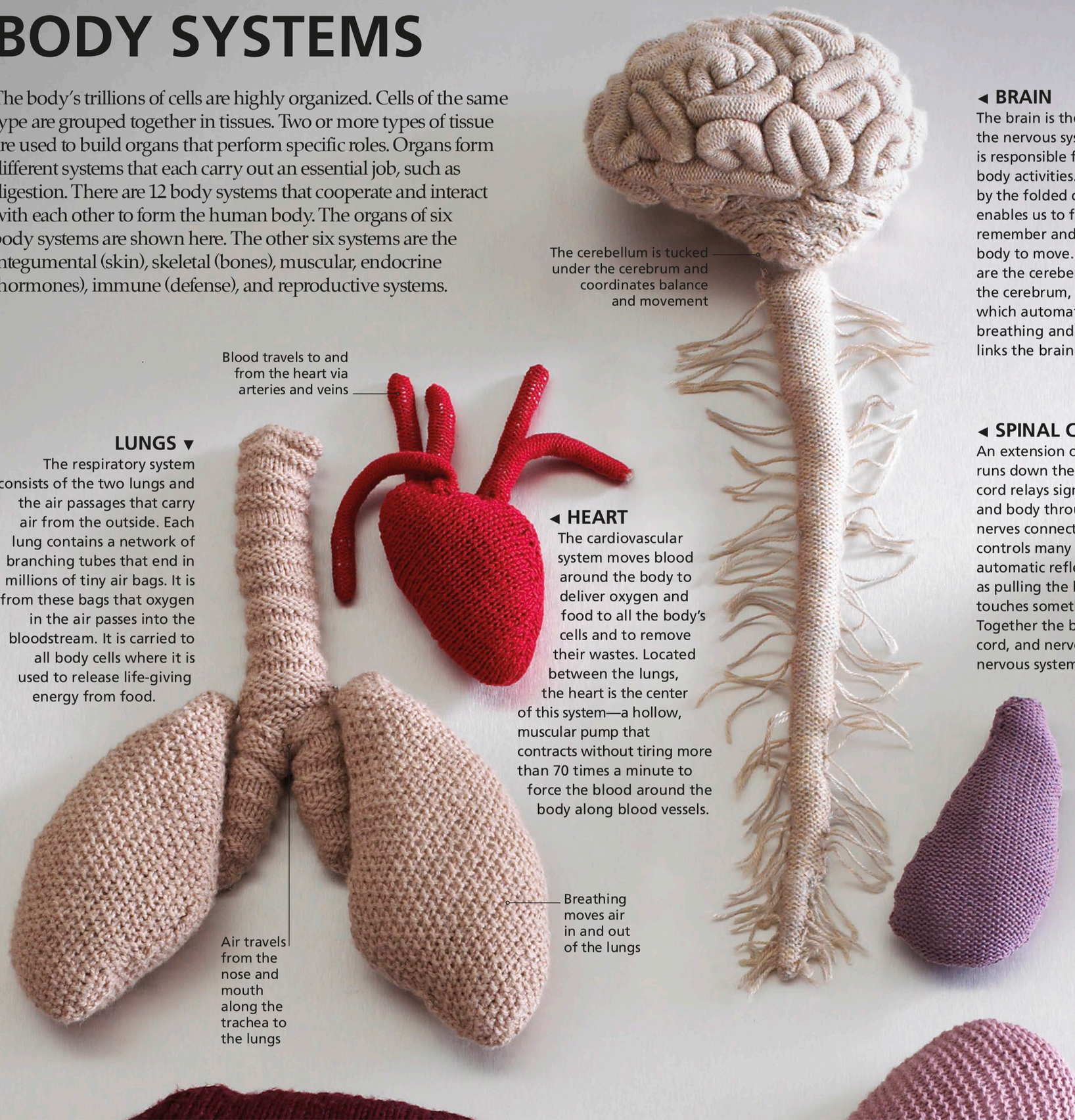
DEEP MUSCLES

REAR MUSCLES

All muscles are given Latin names that describe their size, location, shape, action, or other feature. Working downward from head to feet, skeletal muscles at the rear of the body keep the head upright, steady the shoulders, keep the back upright to maintain posture, pull the arms backward and straighten them, straighten the thighs at the hip and bend the knees, and point the toes downward.

BODY SYSTEMS

The body's trillions of cells are highly organized. Cells of the same type are grouped together in tissues. Two or more types of tissue are used to build organs that perform specific roles. Organs form different systems that each carry out an essential job, such as digestion. There are 12 body systems that cooperate and interact with each other to form the human body. The organs of six body systems are shown here. The other six systems are the integumental (skin), skeletal (bones), muscular, endocrine (hormones), immune (defense), and reproductive systems.



◀ BRAIN
The brain is the center of the nervous system, which is responsible for controlling body activities. It is dominated by the folded cerebrum that enables us to feel, think, and remember and instructs the body to move. Other brain parts are the cerebellum, tucked under the cerebrum, and the brain stem, which automatically controls breathing and heart rate and links the brain to the spinal cord.

◀ SPINAL CORD
An extension of the brain that runs down the back, the spinal cord relays signals between brain and body through the spinal nerves connected to it. It also controls many of the body's automatic reflex actions, such as pulling the hand back if it touches something sharp. Together the brain, spinal cord, and nerves form the nervous system.

LUNGS ▼
The respiratory system consists of the two lungs and the air passages that carry air from the outside. Each lung contains a network of branching tubes that end in millions of tiny air bags. It is from these bags that oxygen in the air passes into the bloodstream. It is carried to all body cells where it is used to release life-giving energy from food.

◀ HEART
The cardiovascular system moves blood around the body to deliver oxygen and food to all the body's cells and to remove their wastes. Located between the lungs, the heart is the center of this system—a hollow, muscular pump that contracts without tiring more than 70 times a minute to force the blood around the body along blood vessels.

◀ SPLEEN
The spleen is part of the lymphatic system, the body's drainage network. It contains white blood cells, which fight infection by destroying bacteria, and also removes worn-out red blood cells from the blood.

Liver stores excess glucose and releases it when the body needs it

▲ LIVER

The largest internal organ, the liver controls the composition of the blood, processing nutrients newly absorbed from the small intestine.

◄ STOMACH

This muscular bag expands as it receives and stores food that has been chewed and swallowed. During storage, the stomach's walls churn food into a part-digested "soup," which is released into the small intestine.

PANCREAS ►

The pancreas releases chemicals called enzymes into the small intestine to aid digestion, and hormones (chemical messengers) into the blood to control levels of glucose—the body's main fuel—in the blood.

The gall bladder stores bile, a fluid that aids fat digestion

The large intestine turns waste into feces (poop) and pushes them out of the body

Each kidney contains a million tiny filtering units that process blood to make urine

The small intestine is a long tube in which most digestion and absorption occurs

Ureter has muscular walls that squeeze urine downward to the bladder

Billions of harmless bacteria digest waste in the large intestine

URINARY SYSTEM ►

Consisting of the kidneys, ureters, bladder, and urethra, the urinary system makes urine and removes it from the body. The kidneys make urine by removing wastes and excess water and salts from the blood, thereby keeping its composition constant. Urine is stored in the bladder and expelled through the urethra at its base.

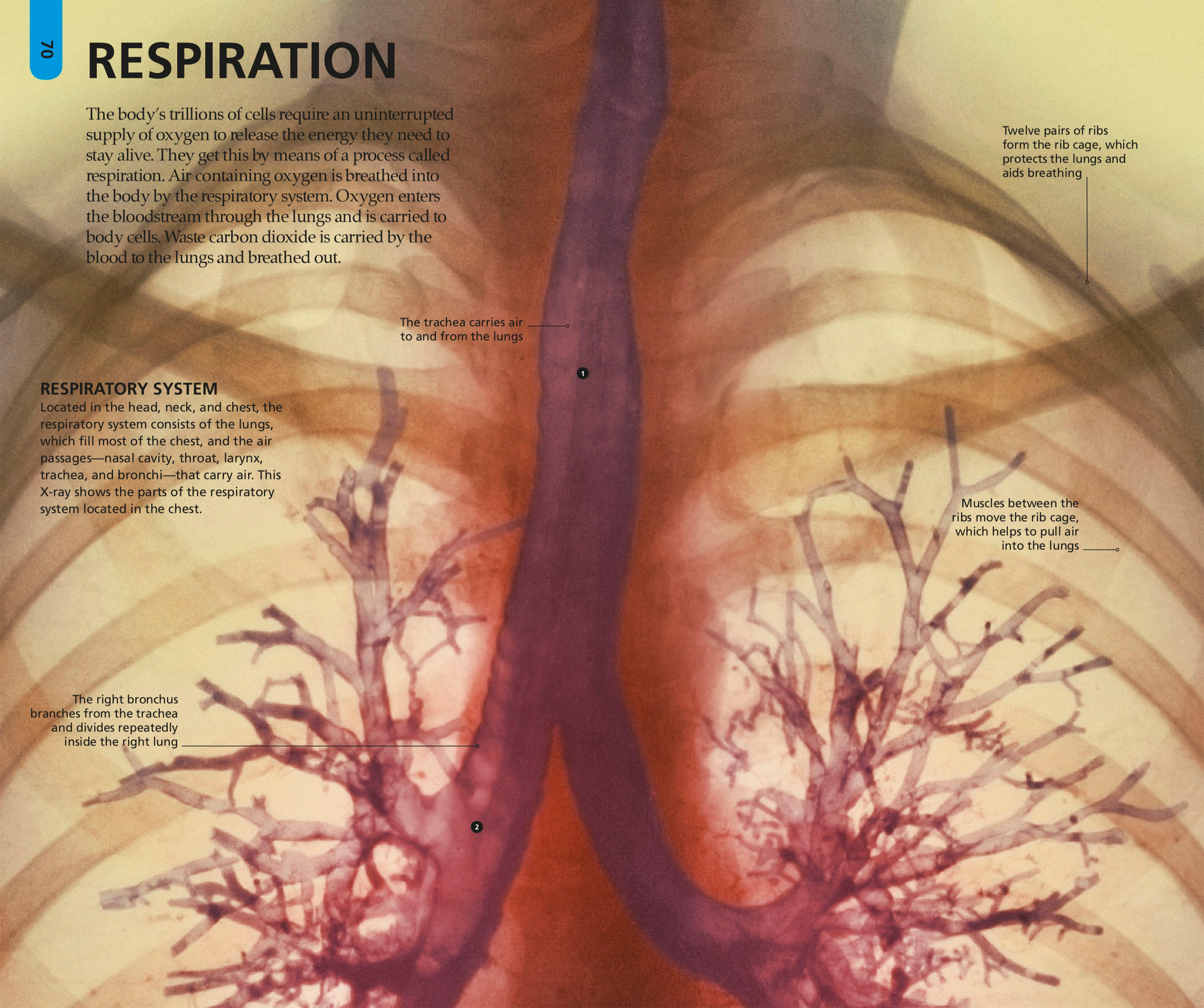
Bladder is a muscular bag that, when filled, pushes urine out through the urethra

DIGESTIVE SYSTEM ►

The body needs nutrients for energy, growth, and repair. The digestive system breaks down food to release these essential nutrients. The system consists of the mouth and teeth, the esophagus (a muscular tube leading from the mouth to the stomach), the stomach, and the small and large intestines. Food is digested using mechanical force, such as chewing, and through chemical digesters called enzymes. Nutrients are then absorbed into the blood and carried to the body's cells.

RESPIRATION

The body's trillions of cells require an uninterrupted supply of oxygen to release the energy they need to stay alive. They get this by means of a process called respiration. Air containing oxygen is breathed into the body by the respiratory system. Oxygen enters the bloodstream through the lungs and is carried to body cells. Waste carbon dioxide is carried by the blood to the lungs and breathed out.



RESPIRATORY SYSTEM

Located in the head, neck, and chest, the respiratory system consists of the lungs, which fill most of the chest, and the air passages—nasal cavity, throat, larynx, trachea, and bronchi—that carry air. This X-ray shows the parts of the respiratory system located in the chest.

❶ TRACHEA

Also called the windpipe, this flexible tube carries air between the larynx (voice box) at the base of the throat and the two bronchi that arise at its lower end. Up to 20 C-shaped rings of cartilage that encircle the trachea hold it open during breathing in. Mucus lining the trachea cleans the incoming air by trapping dirt and germs, a process that began in the nasal cavity.

❷ BRONCHIAL TREE

Once inside a lung, each bronchus divides into smaller bronchi that then spilt even further. These, in turn, divide repeatedly to form smaller branches called bronchioles. This arrangement is often called "the bronchial tree" because its structure looks like an upside-down tree with the trachea as the trunk, bronchi as branches, and bronchioles as twigs.

❸ BRONCHIOLES AND ALVEOLI

The narrowest bronchioles end in 300 million air-filled bags called alveoli that fill most of the lungs and are surrounded by blood capillaries. Oxygen passes through the wall of each alveolus into the bloodstream in exchange for carbon dioxide, which moves in the opposite direction. The alveoli provide a large surface across which this exchange can take place efficiently.

❹ DIAPHRAGM

Situated just below the lungs, the diaphragm plays a key role in breathing. When breathing in, the diaphragm contracts and flattens as muscles pull the ribs upward and outward. This increases the space in the chest so that air is sucked into the lungs. When breathing out the relaxed diaphragm is pushed upward, and the ribs move downward and inward, squeezing air from the lungs.

BLOOD

Flowing all around your body, blood delivers food, oxygen, and other essentials to trillions of cells and removes their wastes. Blood also distributes heat around your body and defends it against infection. Blood is made up of a yellow liquid called plasma in which blood cells float. Red blood cells pick up oxygen in the lungs and deliver it to your body's cells. White blood cells defend the body against disease-causing germs. Blood also contains platelets, which enable it to clot to seal damaged blood vessels. The heart pumps blood around the body along three types of blood vessels. Arteries carry blood away from the heart, while veins return blood to the heart. Microscopic capillaries link arteries and veins and supply blood to cells.

Circulating around the average body are 9 pints (5 liters) of blood.

Oxygen-rich blood in arteries is bright red in color. Oxygen-poor blood in veins is dark purple-red.

Blood is 55 percent plasma and 45 percent blood cells.

One drop of blood contains 250 million red blood cells, 375,000 white blood cells, and 16 million platelets.

Plasma is 90 percent water and contains more than 100 different dissolved substances, including food, waste, hormones, and salts.

White blood cells called neutrophils and macrophages eat germs. Lymphocyte white blood cells disable germs by releasing chemicals called antibodies.

Unraveled and stretched out, one adult's blood vessels would encircle Earth twice. Capillaries would make up 98 percent of the total length.

Each as broad as a thumb, the largest artery and vein (the aorta and vena cava) are 2,500 times wider than a capillary, which is just one-tenth the width of a hair.

Oxygen-carrying red blood cells make up 99 percent of all blood cells.

Every second, 2 million new red blood cells are made by jellylike red marrow inside bones.

During a lifes pan of 120 days, a red blood cell travels around the body 170,000 times—once each minute. It is then dismantled and recycled by the spleen and liver.

Packed into every red blood cell are 250 million red-colored hemoglobin molecules. Each one carries four oxygen molecules, so a single red blood cell can transport 1 billion oxygen molecules.

The heart is made largely of cardiac muscle, which does not tire.

Over a lifetime of 70 years, the heart beats 2.5 billion times without taking a rest.

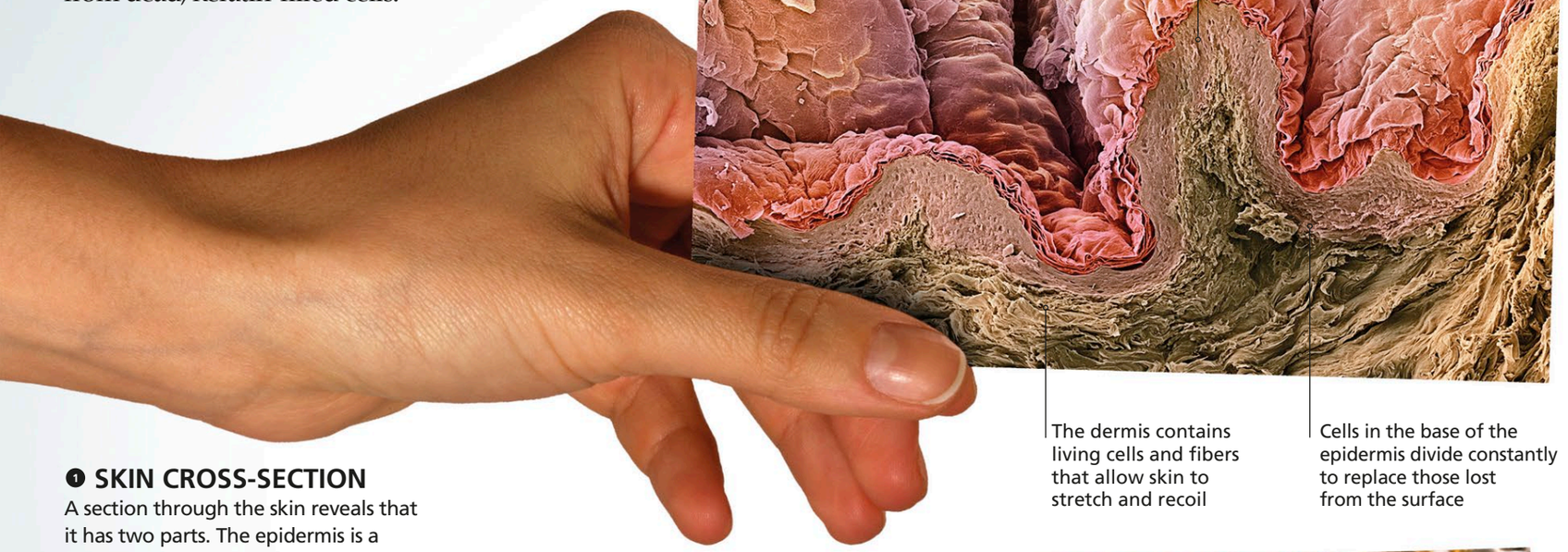
The heart beats, on average, 70 times a minute. Heart rate can double or triple during exercise to get extra oxygen to your muscles.

Each person belongs to one of four blood groups—A, B, AB, or O. Blood groups are determined by tiny "markers" carried by red blood cells.

More than 112.5 million units of blood are donated around the world every year. Blood transfusions replace blood lost during surgery and are used to treat some medical conditions.

SKIN, HAIR, AND NAILS

Skin is the body's protective overcoat, forming a barrier between vulnerable body tissues and the harsh, changing conditions of the outside world. It prevents water loss, blocks invasion by germs, repairs itself when damaged, helps us keep warm, and enables us to sense our surroundings. The uppermost layer of the skin is made from dead cells filled with a tough, waterproof substance called keratin. Hair and nails, both derived from skin, are also made from dead, keratin-filled cells.



❶ SKIN CROSS-SECTION

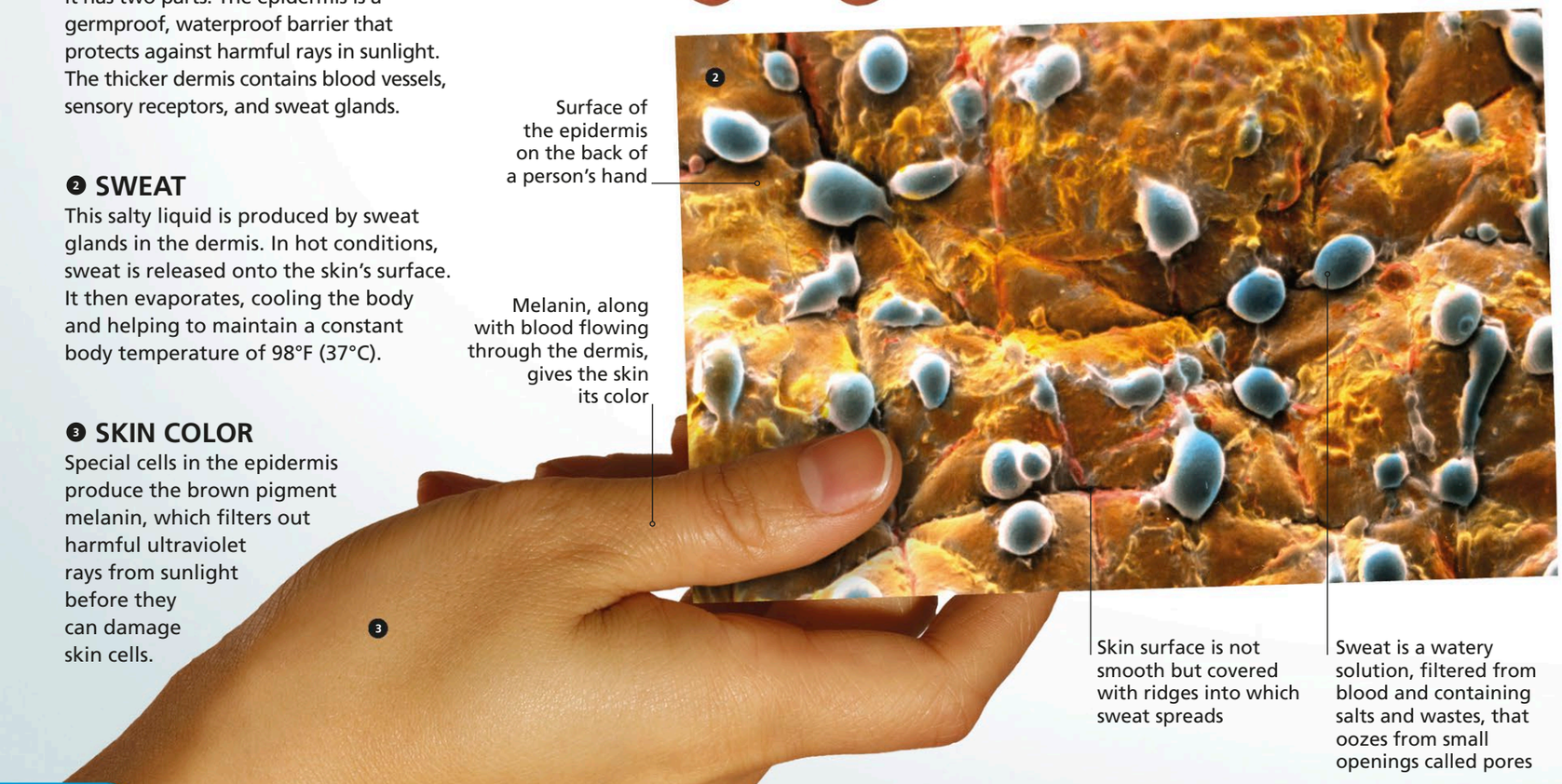
A section through the skin reveals that it has two parts. The epidermis is a germproof, waterproof barrier that protects against harmful rays in sunlight. The thicker dermis contains blood vessels, sensory receptors, and sweat glands.

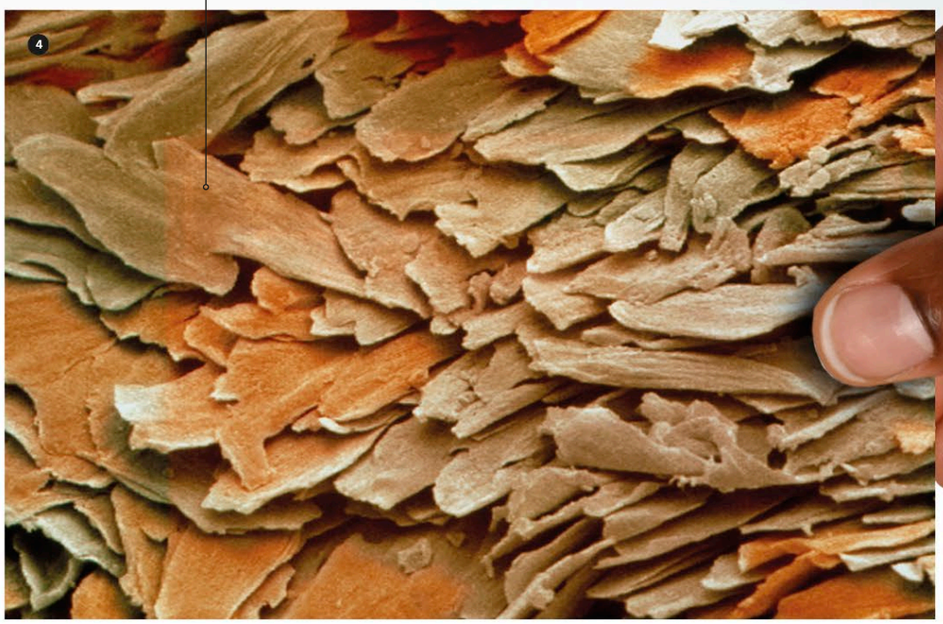
❷ SWEAT

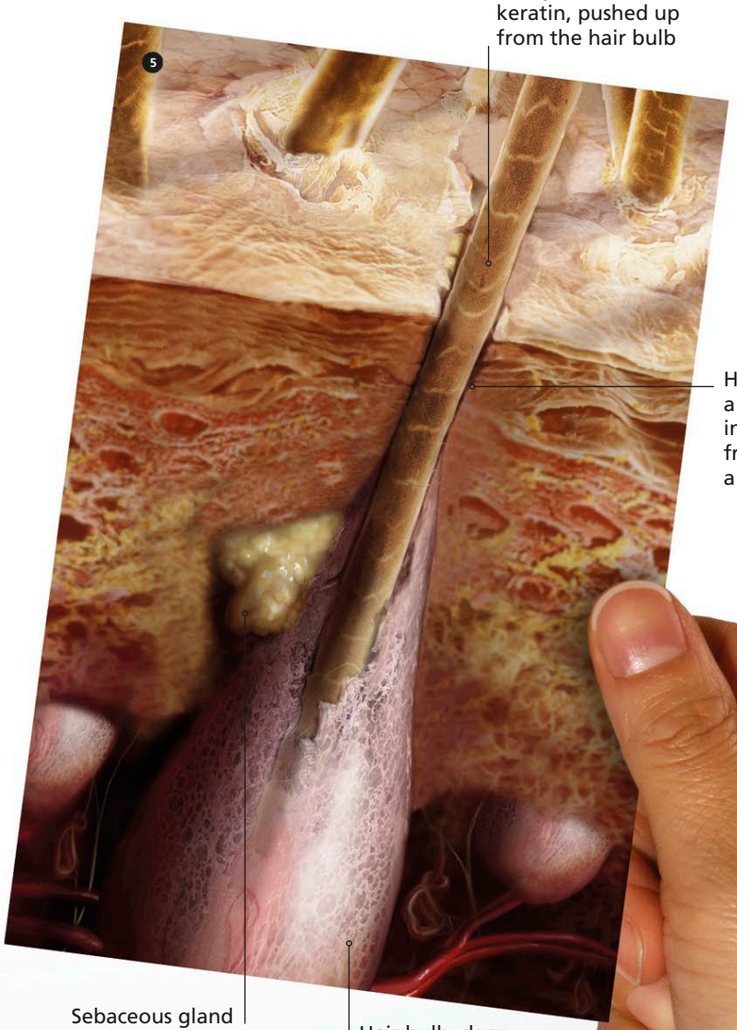
This salty liquid is produced by sweat glands in the dermis. In hot conditions, sweat is released onto the skin's surface. It then evaporates, cooling the body and helping to maintain a constant body temperature of 98°F (37°C).

❸ SKIN COLOR

Special cells in the epidermis produce the brown pigment melanin, which filters out harmful ultraviolet rays from sunlight before they can damage skin cells.







❹ FINGERNAIL

Ideal for gripping objects and scratching itches, fingernails are clear plates that protect the sensitive upper parts of the fingertips. The cells that make nails die, flatten, and fill with keratin as they are pushed forward from the nail's root.

❺ HAIR

Millions of hairs grow from the skin covering most body areas. Scalp hairs protect the skin from sunlight and reduce heat loss. Finer, shorter body hairs sense the presence of insects on the skin before they can sting or bite us.

❻ TOUCH RECEPTORS

The dermis contains a range of receptors that respond to soft touch, firmer pressure, and vibrations and send signals to the brain so we can feel our surroundings. The dermis also has receptors that detect pain, heat, and cold.

BRAIN

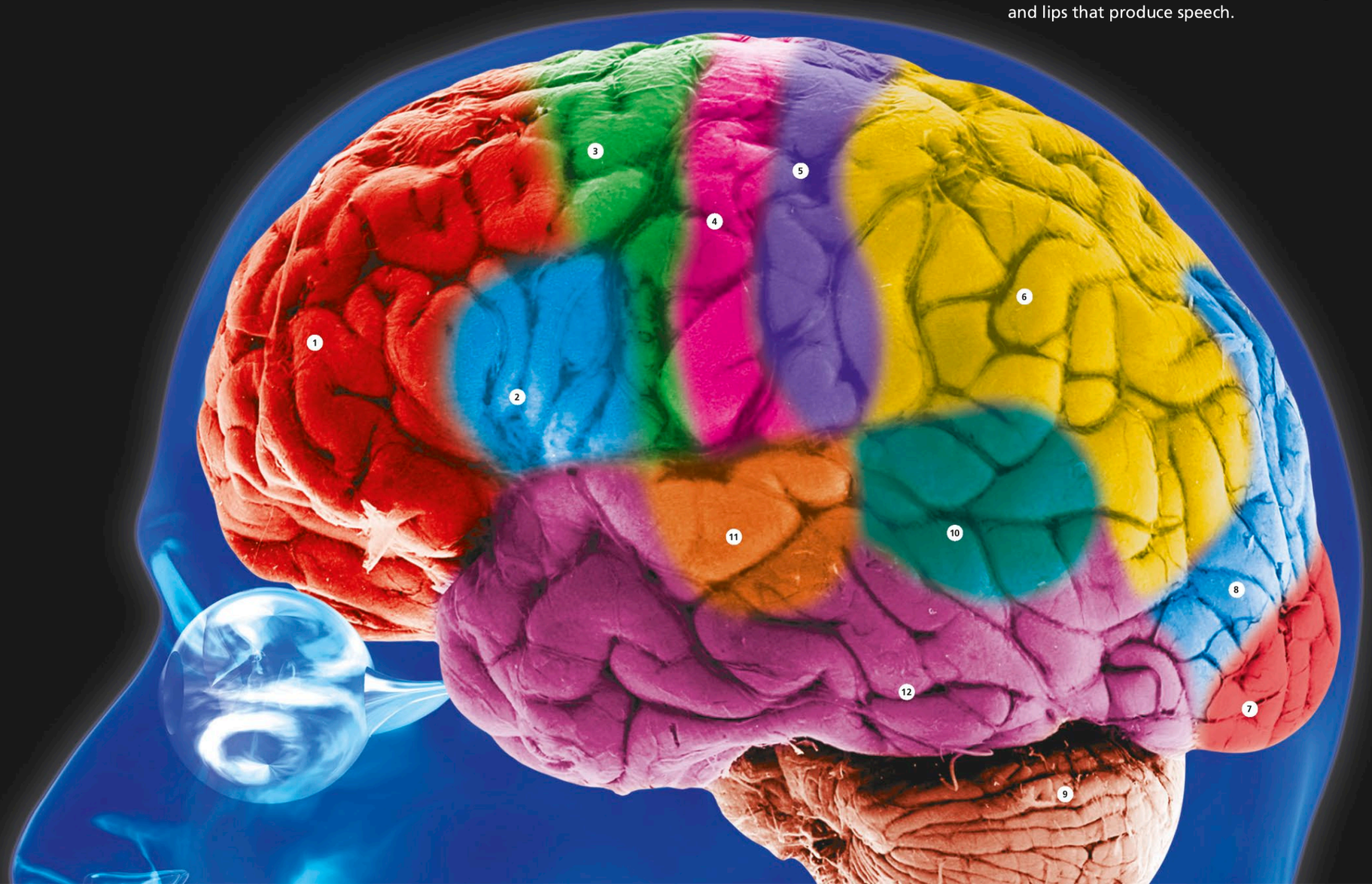
Safely inside the skull, the brain allows us to sense, think, learn, remember, and move. It also automatically regulates vital functions such as breathing. The cerebrum, the main part of the brain, has two halves, or hemispheres. The left hemisphere controls the right side of the body and is in charge of language, math, and problem solving, while the right side controls the body's left side and deals with creativity, music, and art. The cerebrum's many tasks are carried out by its outer layer, or cortex. This has distinct areas that have different roles. Motor areas trigger movement, sensory areas deal with the senses, while association areas interpret information.

❶ PREFRONTAL CORTEX

The most complex part of the cerebrum, the prefrontal cortex makes us what we are. It determines our personality and intellect and enables us to reason, plan, create, and learn complex ideas and have a conscience.

❷ BROCA'S AREA

Named after Paul Broca, the 19th-century doctor who discovered it, Broca's area is normally found in the left hemisphere. It plans what a person wants to say and sends instructions to muscles in the throat, tongue, and lips that produce speech.



❸ PREMOTOR CORTEX
Learned movement skills, such as playing tennis, are controlled and coordinated by the premotor cortex. It tells specific muscles to contract either through the primary motor cortex or, in some cases, directly.

❹ PRIMARY MOTOR CORTEX
Most movements we make are controlled by the primary motor cortex. Guided by information from the cerebellum and other brain parts, it sends instructions to muscles that move the skeleton instructing them when, and in what sequence, to contract.

❺ PRIMARY SENSORY CORTEX
Receptors in the skin for touch, pressure, vibration, heat and cold, and pain send signals to the primary sensory cortex enabling us to feel those sensations. Our lips and fingertips have high concentrations of receptors, hence their sensitivity.

❻ SENSORY ASSOCIATION CORTEX
Basic information about touch, pressure, and other skin sensations is passed on by the primary sensory cortex to the sensory association cortex. Here sensations are analyzed, stored, and compared with previous experiences. It enables us to identify objects by touch.

❼ PRIMARY VISUAL CORTEX
When light hits the retina at the back of each eye, its light detectors send signals to the primary visual cortex. Here those signals are interpreted as basic shapes, colors, and movements before being passed on to the visual association cortex.

❽ VISUAL ASSOCIATION CORTEX
This is where information from the primary visual cortex about seen objects is interpreted and compared with previous visual experiences. The visual association cortex identifies what we are looking at and where it is in space, enabling us to "see" it.

❾ CEREBELLUM
The cerebellum is responsible for producing smooth, coordinated movements of the body. It analyzes incoming information about the body's current position and movement then interacts with the primary motor cortex to precisely time muscle contractions.

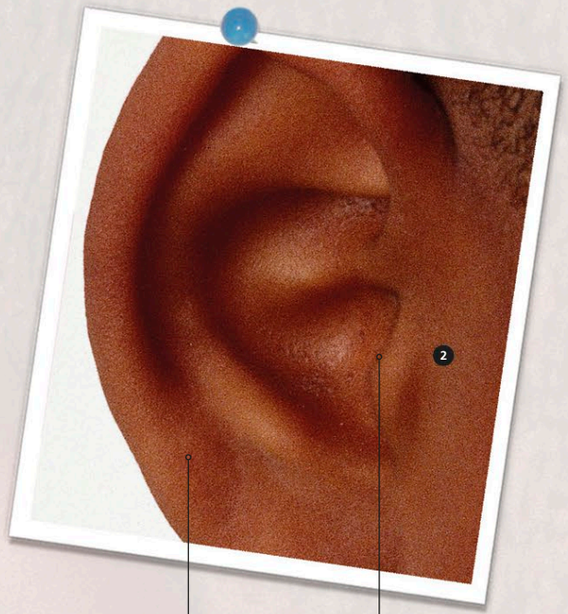
❿ WERNICKE'S AREA
Usually located in the left hemisphere, Wernicke's area gives meaning to words that have been heard or read. Named after the German doctor Karl Wernicke, it has a direct link to Broca's area enabling us to speak the words we hear or see.

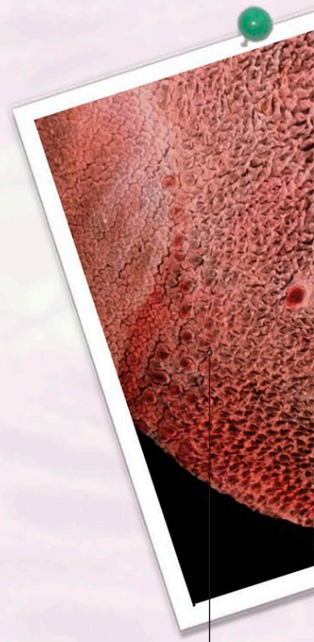
⓫ PRIMARY AUDITORY CORTEX
When sounds are detected by the two ears, they send signals to the primary auditory cortex. Here the loudness, pitch (whether high or low), and rhythm of sounds are identified. That information is passed on to the auditory association area.

⓬ AUDITORY ASSOCIATION AREA
Sounds are "heard" in the auditory association area. Using information received from the primary auditory cortex, it pieces together the complete sound and, by comparing it with sounds stored in memory, identifies it as, for example, music, speech, or thunder.

SENSES

Our senses make us aware of the world around us and the changes that are happening in it. The eyes detect light waves, and the ears sound waves, enabling us to see and hear. The tongue and nose detect dissolved chemicals so we can taste, smell, and enjoy flavors. The skin allows us to feel the texture and warmth of objects.



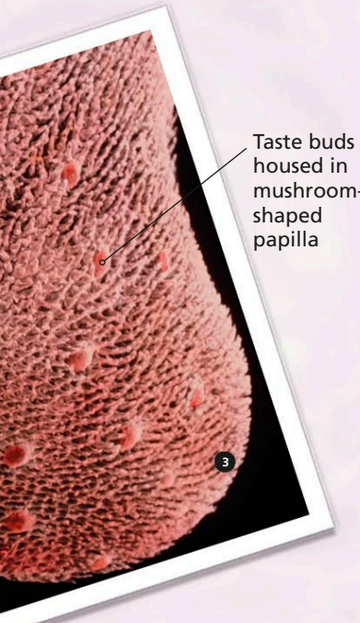


❶ VISION

Vision is the most important sense, providing the brain with an immense amount of information about the body's surroundings. Light reflected from, or produced by, outside objects is automatically focused onto a layer of light receptors that lines the back of the eye. In response, these receptors send signals to areas at the back of the brain. From there, we can determine what we are looking at and where it is, thus enabling us to "see" moving, 3-D images in color.

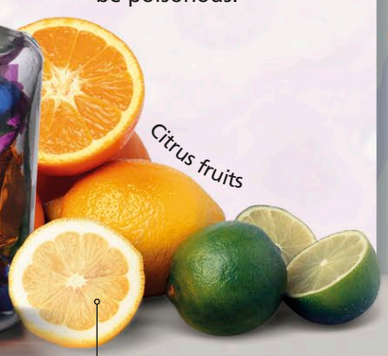
❷ HEARING

The ears detect waves of pressure, called sound waves, that travel through the air. Sound waves are produced by objects, such as a ringing cell phone or bell, which move or vibrate. The waves pass into the inner ear, which is enclosed in bone on the side of the skull. Here, receptors convert pressure waves into signals. The signals travel to the brain, which identifies the pitch, volume, and direction of the sound.

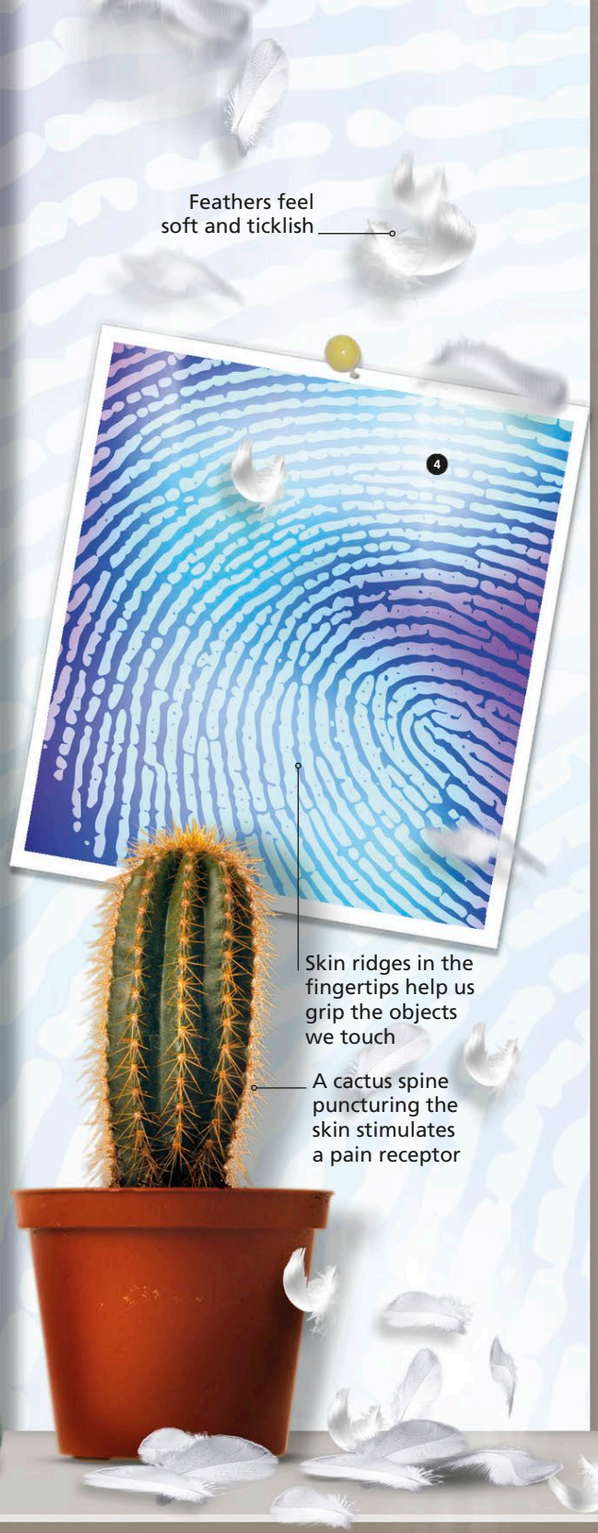


❸ TASTE

Small projections on the tongue, called papillae, house taste receptors called taste buds. Food molecules dissolved in saliva are detected by the taste buds. These can distinguish between five basic tastes—sour, sweet, salty, bitter, and umami (savory and meaty). In addition to helping us to enjoy food, our sense of taste enables us to detect foods that may be poisonous.



Lemons and most other citrus fruits taste sour



❹ TOUCH

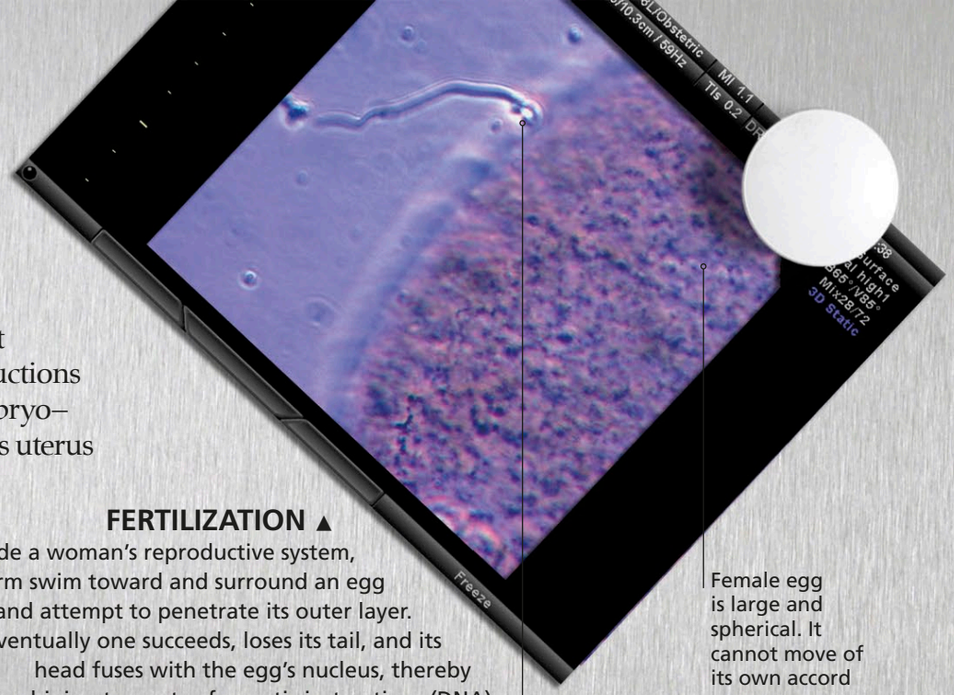
The skin acts like a sense organ. It contains several different types of receptors that enable us to "feel" our surroundings. Most are touch receptors that send signals to the brain when the skin comes into contact with objects. Some detect light touch, some heavier pressure, and some vibrations. Other receptors in the skin pick up temperature changes or detect pain.

❺ SMELL

The nose can detect more than 10,000 different smells. When air is breathed into the nose, odor molecules dissolve in watery mucus and are detected by odor receptors high in the roof of the nasal cavity. Together, the senses of smell and taste enable us to detect flavors. Smell is more important, however, which explains why food lacks flavor when we have a blocked nose. Some smells, such as those produced by burning, can warn us of danger.

REPRODUCTION

Human beings have a limited life span but are able, through reproduction, to produce a new generation to succeed them. Male and female reproductive systems produce specialized sex cells–called sperm and eggs–that unite during fertilization and combine their genetic instructions to make a new, unique human. After fertilization, the embryo–later called a fetus–grows and develops inside its mother's uterus (womb) for the nine months of pregnancy.

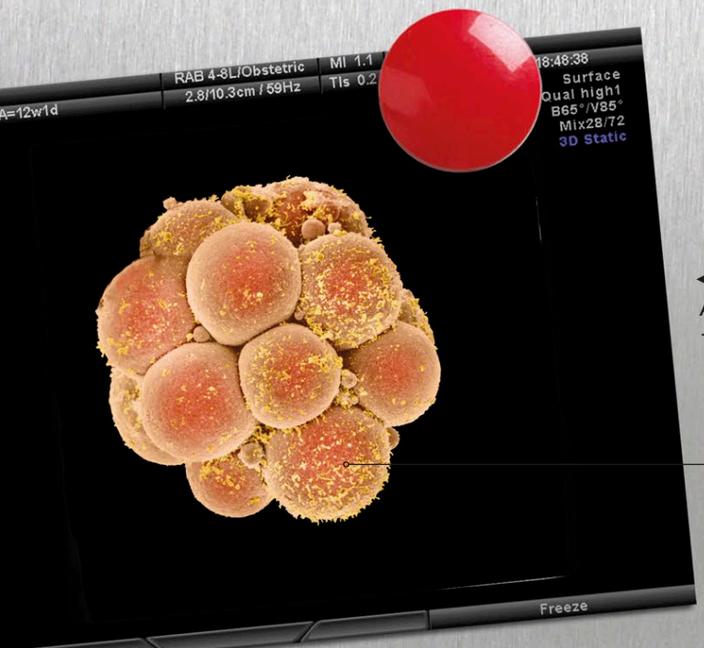


FERTILIZATION ▲

Inside a woman's reproductive system, sperm swim toward and surround an egg and attempt to penetrate its outer layer. Eventually one succeeds, loses its tail, and its head fuses with the egg's nucleus, thereby combining two sets of genetic instructions (DNA).

Female egg is large and spherical. It cannot move of its own accord

Male sperm with beating tail penetrates the outer layer of the egg



◄ CELLS MULTIPLY

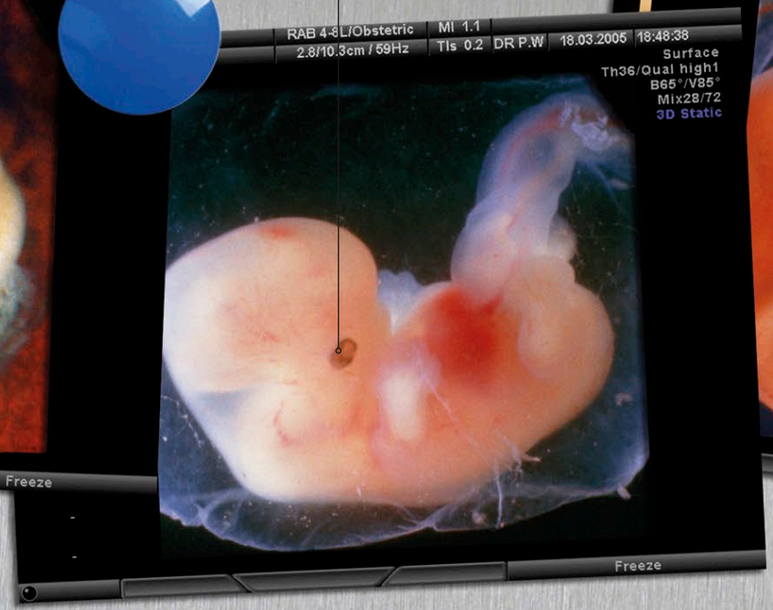
As the fertilized egg, or pre-embryo, is swept toward the uterus, it divides repeatedly, producing first two cells, then four, then eight, and so on. Six days after fertilization, it embeds itself in the uterus lining.

72 hours after fertilization, the pre-embryo is a ball of 16 cells

▲ FOUR WEEKS

This pea-sized, four-week-old embryo—its head is on the left—is growing in its mother's uterus. Its tiny heart is beating, and the nervous system and vital organs are forming.

Dark retina of a developing eye on the side of the embryo's head

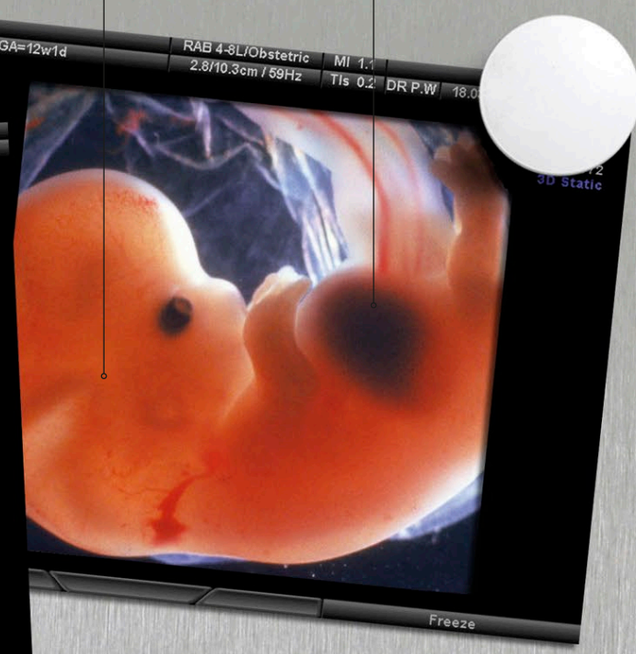


▲ FIVE TO SIX WEEKS

The embryo's brain continues to develop, as do other organs, such as the intestines. Its skull and face are taking shape, and limbs, in the form of buds, are starting to grow. The embryo floats within a sac filled with protective fluid.

The head becomes more erect and the ears, including the organs of balance, develop

The liver makes the embryo's blood cells until bone marrow can take over



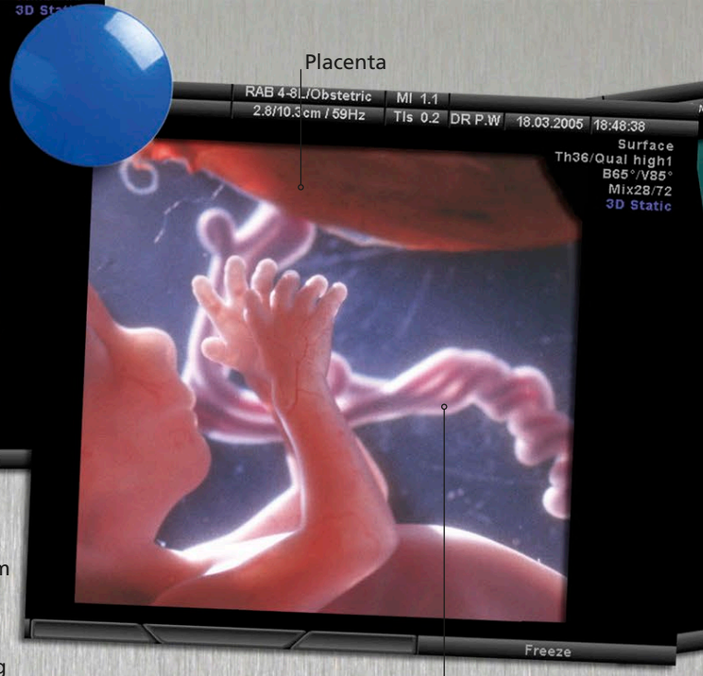
▲ SEVEN WEEKS

The bones of the grape-sized embryo start to harden, and muscles develop and get stronger. Wrists and ankles are now visible, and fingers and toes are just starting to appear. Internally, the kidneys start to remove waste to make urine.

Eyes have moved from the side of the head, and eyelids are forming

▲ TEN WEEKS

Now 500 times bigger than a fertilized egg and consisting of billions of cells of different types, the fetus, as it is now called, has all its basic organs in place and is growing rapidly. Its large head accommodates a fast-expanding brain. Fingers have formed, and fingernails are growing.



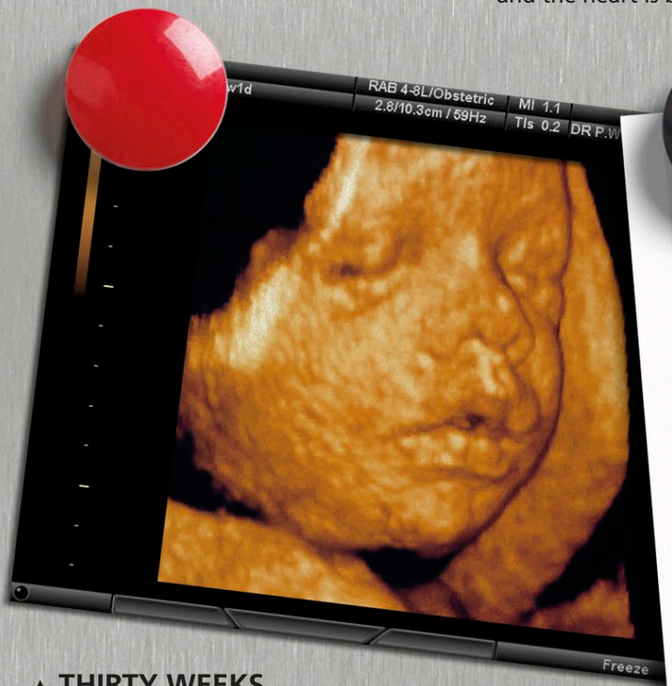
The fetus receives food and oxygen through the umbilical cord, which is connected to the mother via an organ called the placenta

▲ TWELVE WEEKS

Since their implantation, the cells have been growing and specializing, and the tiny individual they have molded is now recognizably human. It has facial features, and fingers and toes have separated. The internal organs are in place, and the heart is beating.

▲ TWENTY WEEKS

Fingers and ears clearly visible, the movements of the fetus can be felt by its mother inside her expanding uterus. The fetus blinks and swallows and follows phases of sleeping and waking. The ridges that produce fingerprints appear on its fingertips.



▲ THIRTY WEEKS

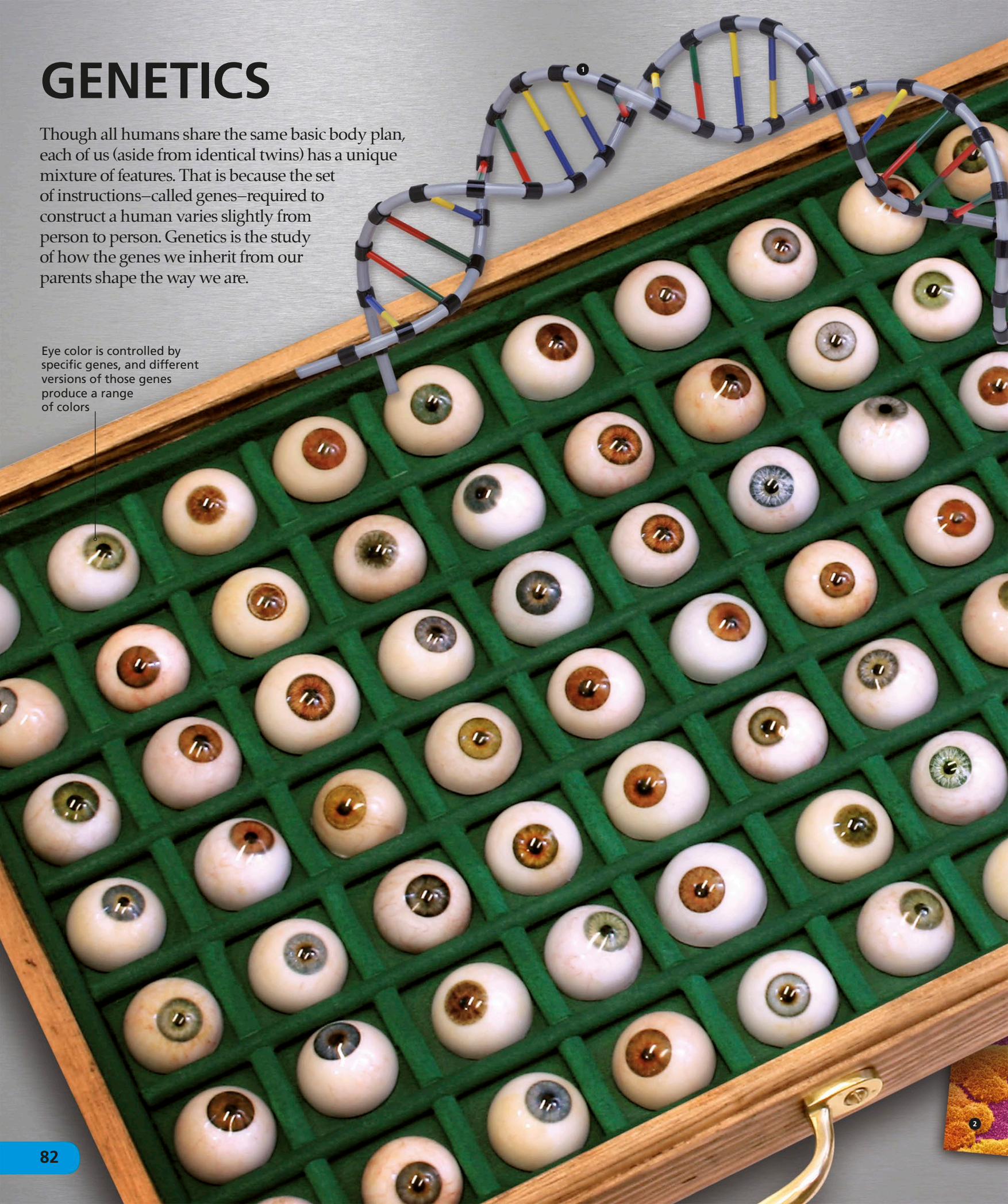
Ultrasound scanning, shown here, is a safe method used to monitor the development of a fetus and can also reveal whether it is a girl or boy. At this stage, the brain is still growing rapidly. The fetus can hear sounds, and its eyes respond to light. Its lungs can now potentially breathe air.

NEWBORN

As pregnancy comes to an end, the uterus contracts to push the fully grown fetus into the bright, noisy outside world. The newborn baby takes its first breath and the umbilical cord is cut. In the next phases of its growth and development, the baby is completely dependent on its parents for food, warmth, and protection.

GENETICS

Though all humans share the same basic body plan, each of us (aside from identical twins) has a unique mixture of features. That is because the set of instructions–called genes–required to construct a human varies slightly from person to person. Genetics is the study of how the genes we inherit from our parents shape the way we are.



Eye color is controlled by specific genes, and different versions of those genes produce a range of colors

❷ CHROMOSOMES

A cell's DNA molecules are packaged into 23 pairs of chromosomes, which are found in the nucleus, the cell's control center. Normally, they are long and thin, but when a cell prepares to divide into two new cells, each chromosome shortens—as its DNA coils up—and duplicates, taking on the X shape shown here.

❸ INHERITANCE

We inherit half of our chromosomes from each of our parents. A set of 23 chromosomes contains about 25,000 genes. Maternal and paternal chromosomes carry matching pairs of each gene—such as the gene that controls eye color—but not necessarily the same version. If two versions are present, only one—the dominant gene—has an effect.

❶ DNA

Long molecules of DNA (deoxyribonucleic acid) are found in every body cell. When magnified, DNA resembles a twisted ladder with "rungs" made from four types of chemicals called bases (shown in color). The sequence of bases along a section of DNA forms an instruction—a gene—for making one of the proteins that build and run a cell.

❹ GENETIC SIMILARITY

As brothers and sisters inherit a selection of genes from the same two people, their parents, they are more likely to resemble each other than they would a nonrelative. Identical twins share almost identical genes, so they look the same and are of the same sex.

NUTRITION

Eating a balanced diet is an important part of good health. The food we eat supplies the nutrients required to build and repair the body and to provide it with energy. Most of our nutrition consists of three food types–carbohydrates, proteins, and fats–but vitamins and minerals are also needed in tiny amounts. Water and dietary fiber are other key components. To remain healthy, a person should eat a variety of food in the correct proportion. Carbohydrates, the body's main source of energy, come in two forms–complex carbohydrates and sweet-tasting sugars.

◂ SUGARS

Foods such as sweets, cakes, and cookies should be eaten sparingly because they contain lots of added sugar. Eating large amounts of sugar gives the body sudden bursts of energy rather than the constant stream it obtains from complex carbohydrates. Sugar that is excess to requirements is stored as fat, causing a person to put on weight.

FATS AND OILS ▸

Although fats and oils supply vitamins and are essential to the functioning of the body, they should be consumed in moderation. Plant oils, such as olive oil, contain unsaturated fatty acids (as do oily fish), which are good for health. However, saturated fatty acids, contained in many animal foods and added to processed foods, can clog arteries.

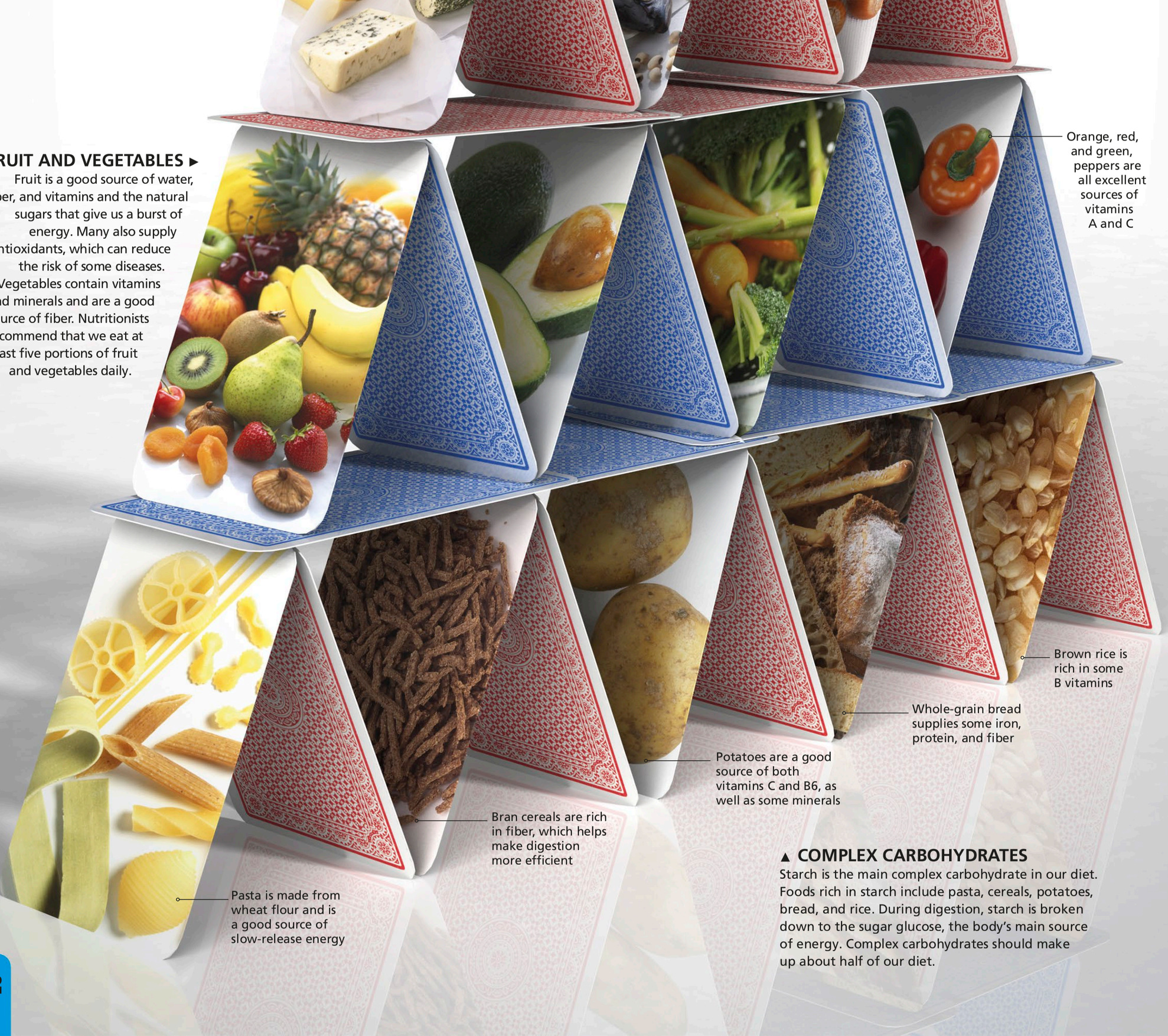
Good-quality chocolate supplies some useful nutrients but can also be high in fat and sugar

Olive oil, like all unsaturated fats, is liquid at room temperature

PROTEINS AND DAIRY FOODS ▸

About 15 percent of our diet should include proteins needed for growth and repair. Foods rich in proteins include nuts, beans, eggs, fish, and meat. Red meat is also rich in saturated fat, harmful to health if eaten in excess. Dairy foods, such as milk and cheese, supply the bone-building mineral calcium and some protein but can also be high in fats.

Walnuts are rich in omega-3 fatty acids, which are essential for good health



FRUIT AND VEGETABLES ▸

Fruit is a good source of water, fiber, and vitamins and the natural sugars that give us a burst of energy. Many also supply antioxidants, which can reduce the risk of some diseases. Vegetables contain vitamins and minerals and are a good source of fiber. Nutritionists recommend that we eat at least five portions of fruit and vegetables daily.

▲ COMPLEX CARBOHYDRATES

Starch is the main complex carbohydrate in our diet. Foods rich in starch include pasta, cereals, potatoes, bread, and rice. During digestion, starch is broken down to the sugar glucose, the body's main source of energy. Complex carbohydrates should make up about half of our diet.

HEALTH

A healthy body is one that is fit, strong, supple, and working well. Disease and injury prevent the normal working of the body. While it is not always possible to avoid illness, the chances of developing a disease are reduced by adopting a healthy lifestyle, including getting regular exercise and eating a good, mixed diet of fresh foods. If a person does become ill, a doctor has to figure out exactly what the problem is and then decide on a suitable course of treatment. This might include drugs, surgery, or other means to return the person to full health.

DRUGS

Chemicals that are used to treat and prevent disease, by changing some aspect of the way the body works, are called drugs. Antibiotics, which kill harmful bacteria, and analgesics, which reduce pain, are both examples of drugs. They may be given to a patient in a number of ways—by injection, as pills and syrups that are swallowed, or as a vapor that is inhaled into the lungs.

Inhaler is used to introduce drugs, such as those that treat asthma, into the lungs

Hypodermic syringe is used to inject drugs into the bloodstream, skin, or a muscle

Laryngeal mirror is placed in the mouth to check the larynx (voice box)

Otoscope has a lens and a light and is used to look into a patient's ear

Ophthalmoscope enables a doctor to examine the inside of a patient's eye

Stethoscope is used to listen to chest sounds such as breathing and heartbeat

DIAGNOSIS

If a person is ill, his doctor first needs to determine exactly what is wrong with him. This is called making a diagnosis. The doctor asks about symptoms—the features of the disease or injury the patient has noticed—and considers the patient's medical history. Next, the doctor looks for signs to help identify the illness, for example, using a thermometer to check body temperature. The patient may require further tests, such as blood tests or X-rays.

FIRST AID

The initial treatment to a person who is sick or injured is called first aid. It is often carried out by someone who is not medically qualified but has been trained to use simple yet effective treatments. In more serious cases, first aid may keep a person alive until medical help arrives. A first-aid kit contains essential items such as disposable gloves, scissors, antiseptic cream and wipes, adhesive bandages, sterile dressings, and bandages.

Blue adhesive bandages are used by caterers because they are easy to spot if they fall in food

Running shoes are ideal footwear for running and other exercises that improve fitness

Dumbbell weight

Chicken is a meat that is rich in protein but low in harmful fats

PREVENTION

Regular exercise, such as running, walking, or playing sports, improves fitness by making the heart and body muscles more efficient. It is also important to eat a balanced diet made up of a wide range of foods—including pasta and rice, fruits and vegetables, lean meat, and oily fish—and low in salt, sugar, and in the unhealthy fats found in red meat. Not only does a healthy diet reduce the risk of becoming overweight, but it can also help protect against certain diseases.

Oranges, like all fruits, contain vitamins that are essential for good health

Fish, especially oily fish, contain fatty acids that can reduce the risk of heart disease

Elasticated bandages support joints, limit swelling, and secure dressings that control bleeding

SURGERY

Performed by a doctor called a surgeon, surgery involves cutting into a patient's body to repair, remove, or replace tissue damaged by disease or injury. Surgery takes place in an operating room. To reduce the risk of infection, staff wear gowns and masks, and everything is sterile (free of germs). During an operation, the patient is given an anesthetic—a drug or gas that stops them from feeling any pain.

Sterile surgical instruments are the "tools" used by a surgeon to perform operations

Antiseptic cream

Sterile dressing

Disposable gloves

Coarse forceps

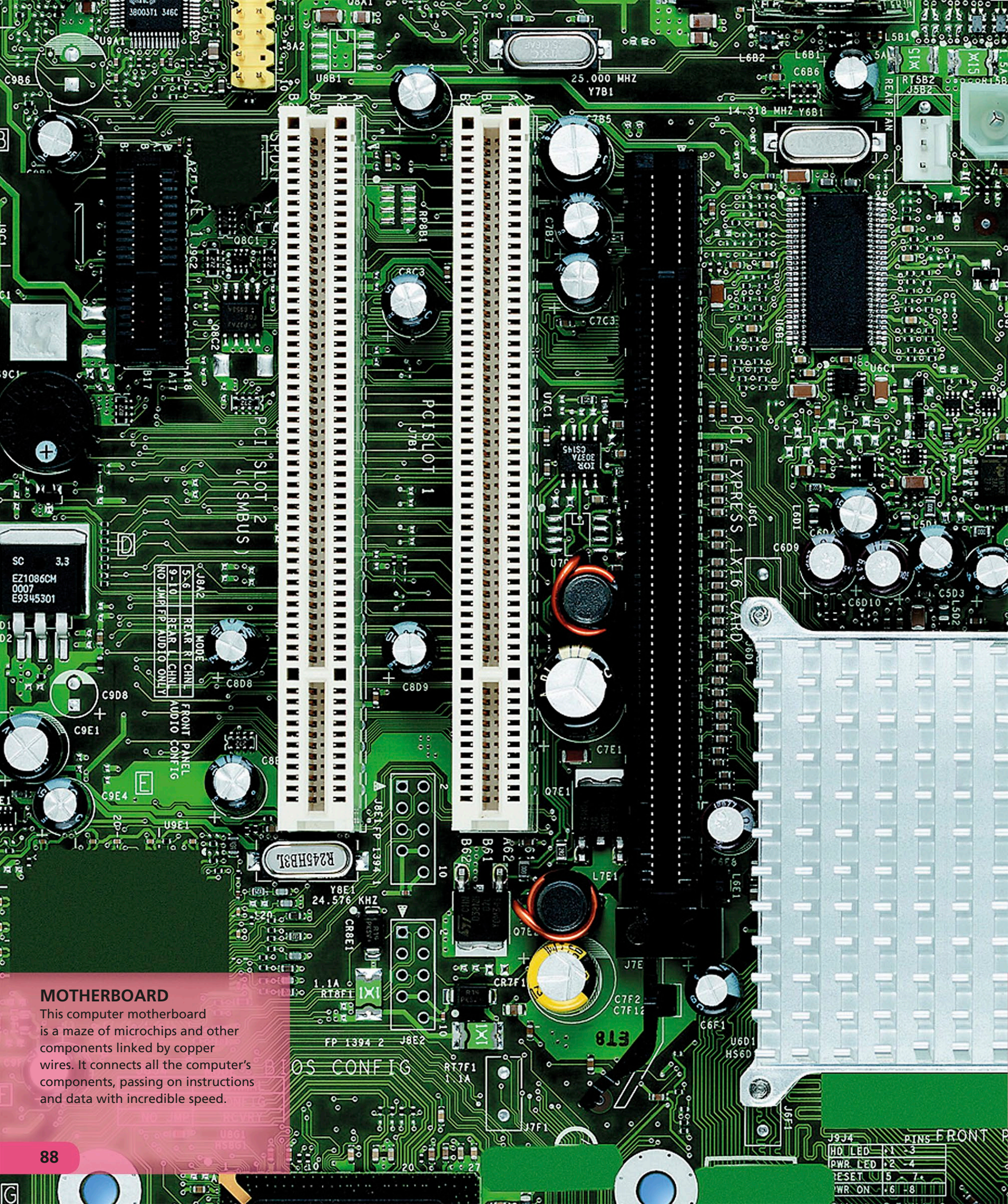
Fine scissors

Coarse scissors

Scalpel is a sharp blade for cutting through skin and other tissues

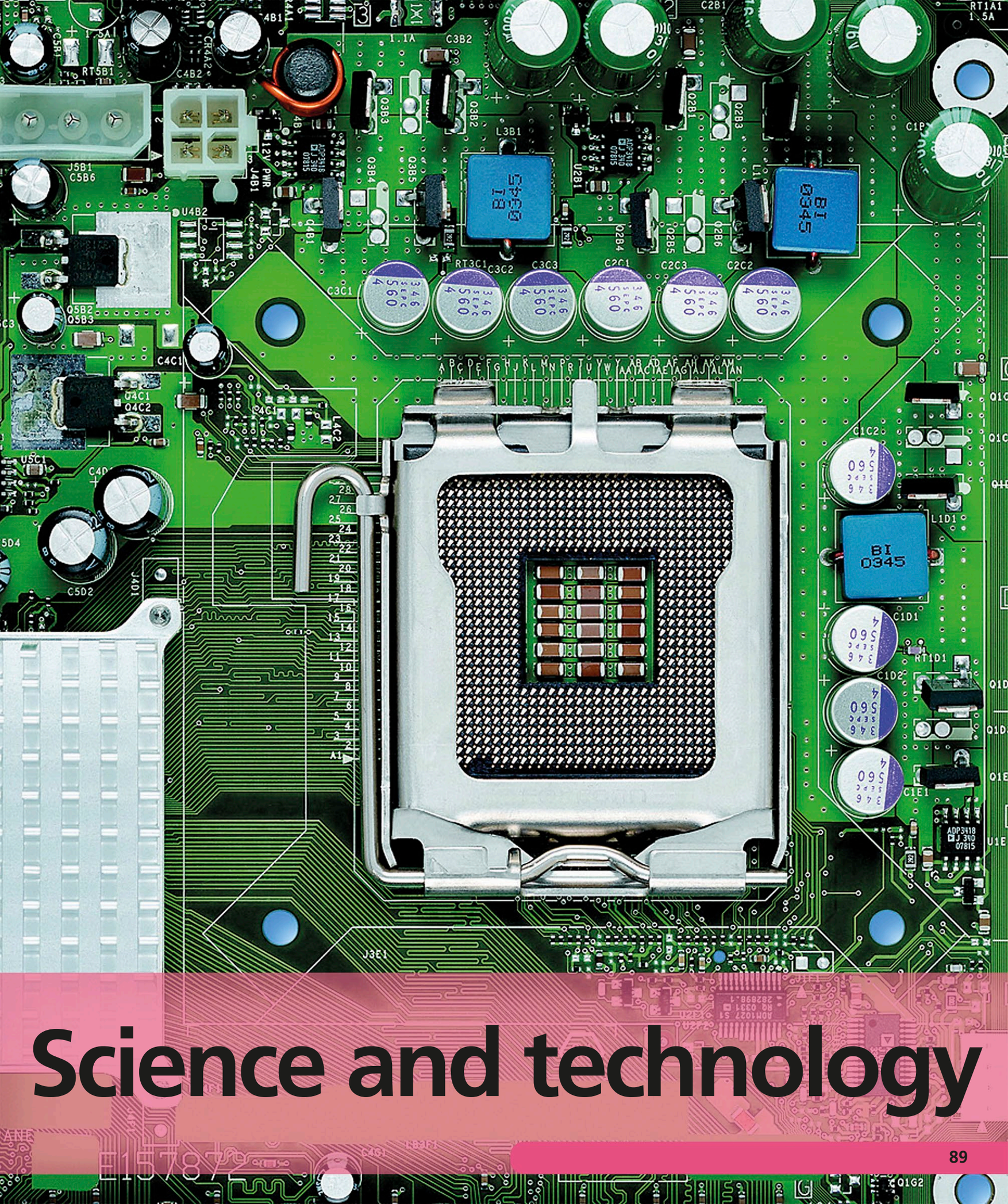
Fine forceps are used to grip and lift tissues during an operation

Probes



MOTHERBOARD

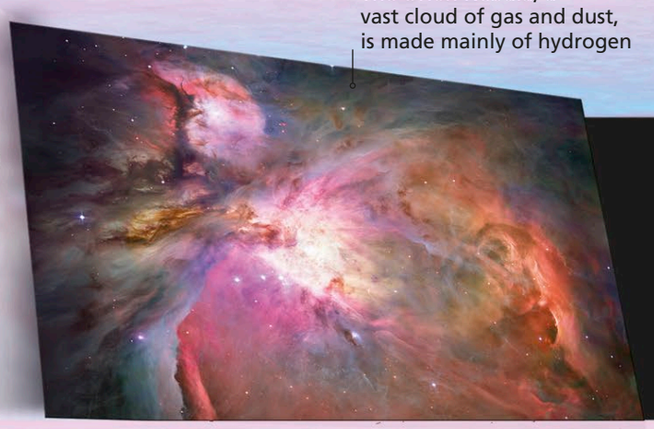
This computer motherboard is a maze of microchips and other components linked by copper wires. It connects all the computer's components, passing on instructions and data with incredible speed.



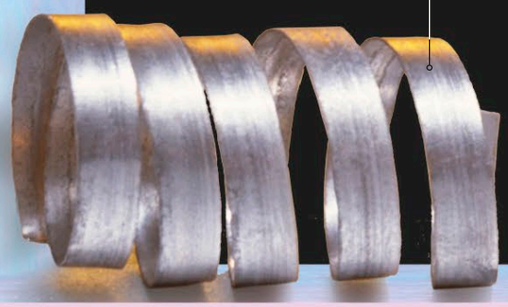
Science and technology

ELEMENTS

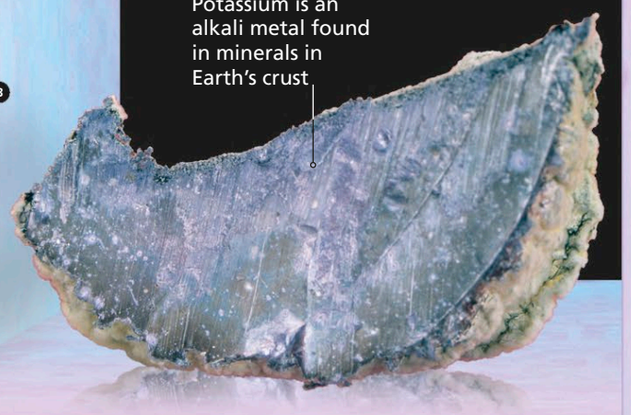
Everything in the world is made from elements–pure substances that cannot be broken down into anything simpler. Elements can be grouped according to the properties they have in common, such as their appearance, how they conduct electricity, and how they react with other substances. There are nine main groups and the element hydrogen, which is unique.



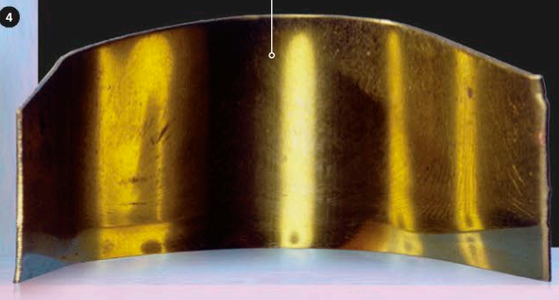
The Orion Nebula, a vast cloud of gas and dust, is made mainly of hydrogen



Magnesium is a silvery substance that burns with a dazzling white flame



Potassium is an alkali metal found in minerals in Earth's crust



Copper is a good conductor of heat and electricity

Radioactive sign is used to show elements that emit radiation

❶ HYDROGEN

Hydrogen makes up 90 percent of all the matter in the universe. Pure hydrogen is an invisible gas on Earth. It is not considered part of any one group. Hydrogen powers the nuclear reactions inside stars, including our sun, and is found on Earth in the compound H_2O, or water.

❷ ALKALINE-EARTH METALS

Alkaline-earth metals react with water and are found in minerals in Earth's crust. In pure form, they are silvery-white. They are similar to alkali metals but less reactive. Calcium, found in chalk, milk, and bones, is a member of this group.

❸ ALKALI METALS

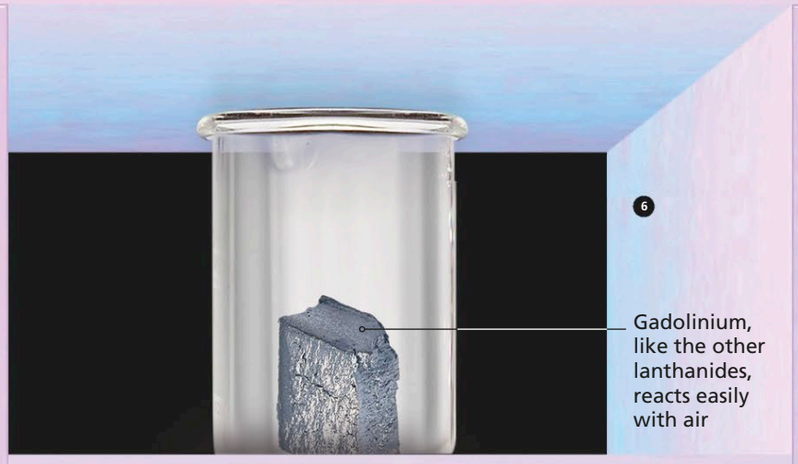
Sodium, contained in salt, is an alkali metal. These elements are characterized by their vigorous reaction with water. On contact, they will zoom all over the water's surface or even explode. Alkali metals are not found in a pure form in nature because they react so strongly with water.

❹ TRANSITION METALS

This group is the largest and includes iron, silver, gold, nickel, platinum, and titanium. Transition metals are considered typical metals—they are hard and shiny, conduct electricity and heat well, and have high melting points.

❺ ACTINIDES

The elements in this group are radioactive metals mostly created synthetically in nuclear reactors or nuclear explosions. They have unstable atoms that break up and give out radiation particles. Uranium and plutonium are examples of actinides.



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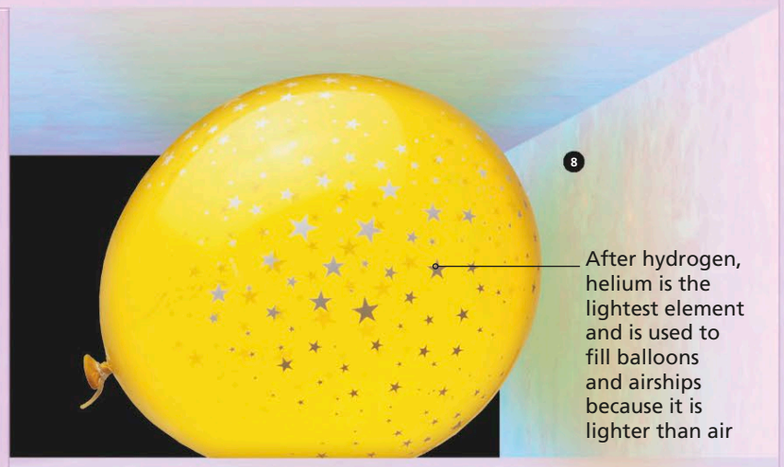
Gadolinium, like the other lanthanides, reacts easily with air



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After hydrogen, helium is the lightest element and is used to fill balloons and airships because it is lighter than air

The halogen bromine is a red-brown liquid at room temperature but evaporates quickly to form a choking, poisonous gas

7

Tin is often made into alloys—mixing it with copper makes bronze, while combining it with lead forms pewter

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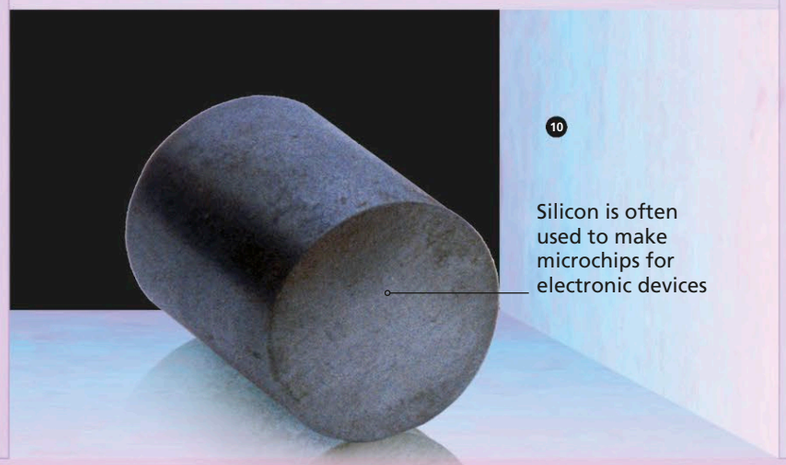

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Silicon is often used to make microchips for electronic devices

6 LANTHANIDES

These soft, reactive metals were known as rare earths, because they were wrongly believed to occur only scarcely in nature. Silvery-white in appearance, they tarnish easily on contact with air. Holmium, the element with the greatest magnetic strength, is in this group.

7 NONMETALS

Around one-sixth of elements are nonmetals. They are poor conductors of electricity and melt at low temperatures. Carbon, nitrogen, and oxygen are all examples of nonmetals, as are the halogens, a group of highly reactive elements that combine with other elements to form salts.

8 NOBLE GASES

There are seven noble gases—also called rare or inert gases because they do not readily react with anything or combine with other elements to make compounds. They are helium, neon, argon, krypton, xenon, radon, and oganesson, although the latter may be a solid at room temperature.

9 POOR METALS

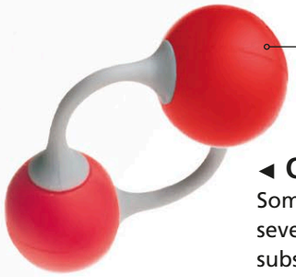
Metals that are fairly soft and melt easily are known as poor metals. They are readily found as ores (minerals) in Earth and can be very useful, especially when made into alloys (two metals mixed together to make a harder metal). Aluminum and lead are both poor metals.

10 SEMIMETALS

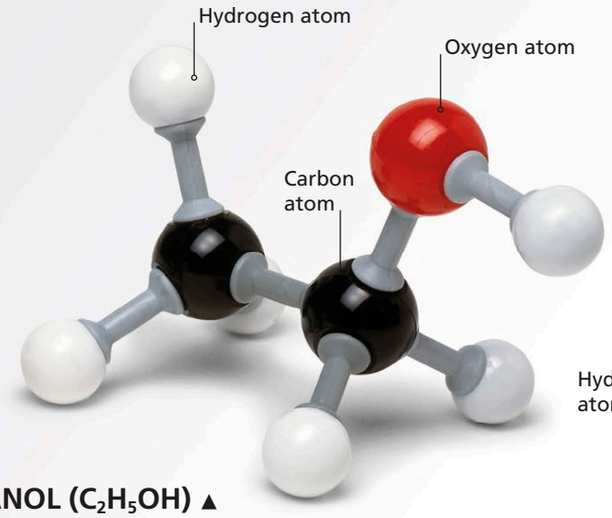
These elements have some properties of metals and some of nonmetals. Arsenic, for example, is shiny like a metal but not a good conductor. Some semimetals are semiconductors, behaving as conductors or insulators depending on what other substances are added to them.

MOLECULES

An element is a substance made of only one kind of atom. Atoms join, or bond, to other atoms of the same element or to atoms of other elements. They do this by sharing or exchanging electrons. In many cases, the bonded atoms form groups called molecules. When atoms of one element combine with atoms of other elements, they form compounds.

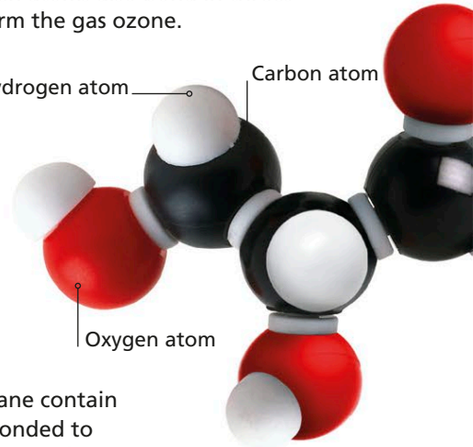


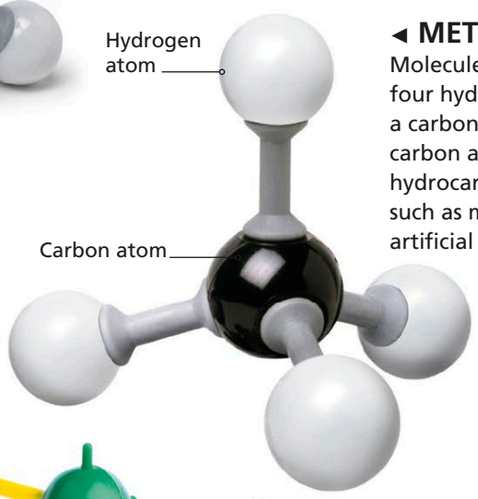
◄ OXYGEN (O_2)
Some elements can bond in several ways to form different substances. Atoms of the element oxygen (O) bond together in pairs to form molecules of oxygen gas. High in the atmosphere, however, oxygen atoms also bond in threes to form the gas ozone.



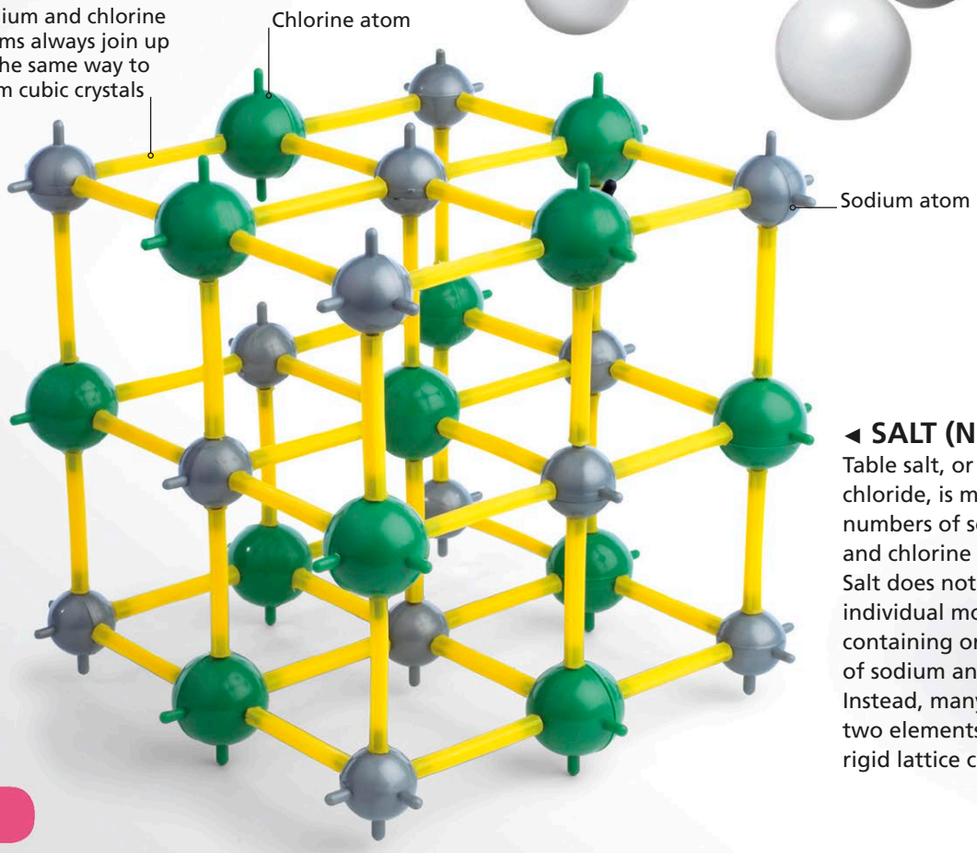
ETHANOL (C_2H_5OH) ▲
Ethanol is a compound with molecules containing two carbon (C) atoms, six hydrogen (H) atoms, and one oxygen (O) atom. At room temperature, it is a colorless liquid used as a disinfectant, preservative, and the alcohol in drinks.

VITAMIN C ($C_6H_8O_6$) ►
Like ethanol, vitamin C (ascorbic acid) contains carbon (C), hydrogen (H), and oxygen (O) atoms. However, because the molecule contains different quantities of the elements arranged in a different way, it forms an entirely different substance—a compound that is solid at room temperature.

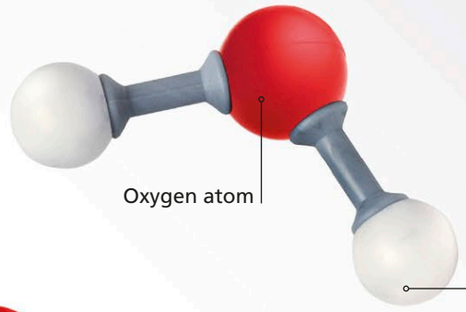




◄ METHANE (CH_4)
Molecules of the gas methane contain four hydrogen (H) atoms bonded to a carbon (C) atom. Compounds of carbon and hydrogen are called hydrocarbons. They include fuels, such as methane, oil, and coal, and artificial materials, such as polystyrene.

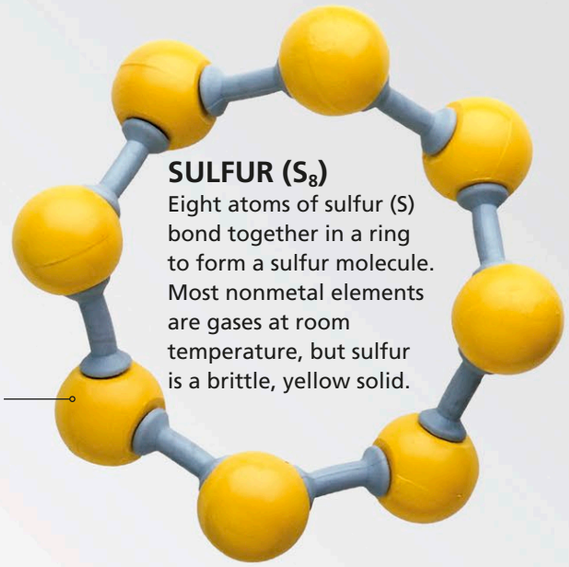


◄ SALT (NaCl)
Table salt, or sodium chloride, is made of equal numbers of sodium (Na) and chlorine (Cl) atoms. Salt does not form as small individual molecules containing one atom each of sodium and chlorine. Instead, many atoms of the two elements link to form a rigid lattice called a crystal.



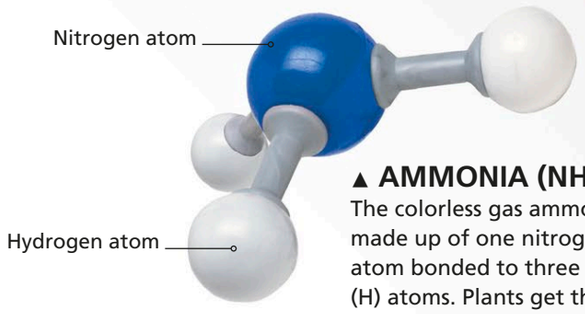
◂ WATER (H_2O)

When two atoms of the gas hydrogen (H) bond with one atom of the gas oxygen (O), they form molecules of liquid water. Water is the most common compound on Earth and is essential for life.



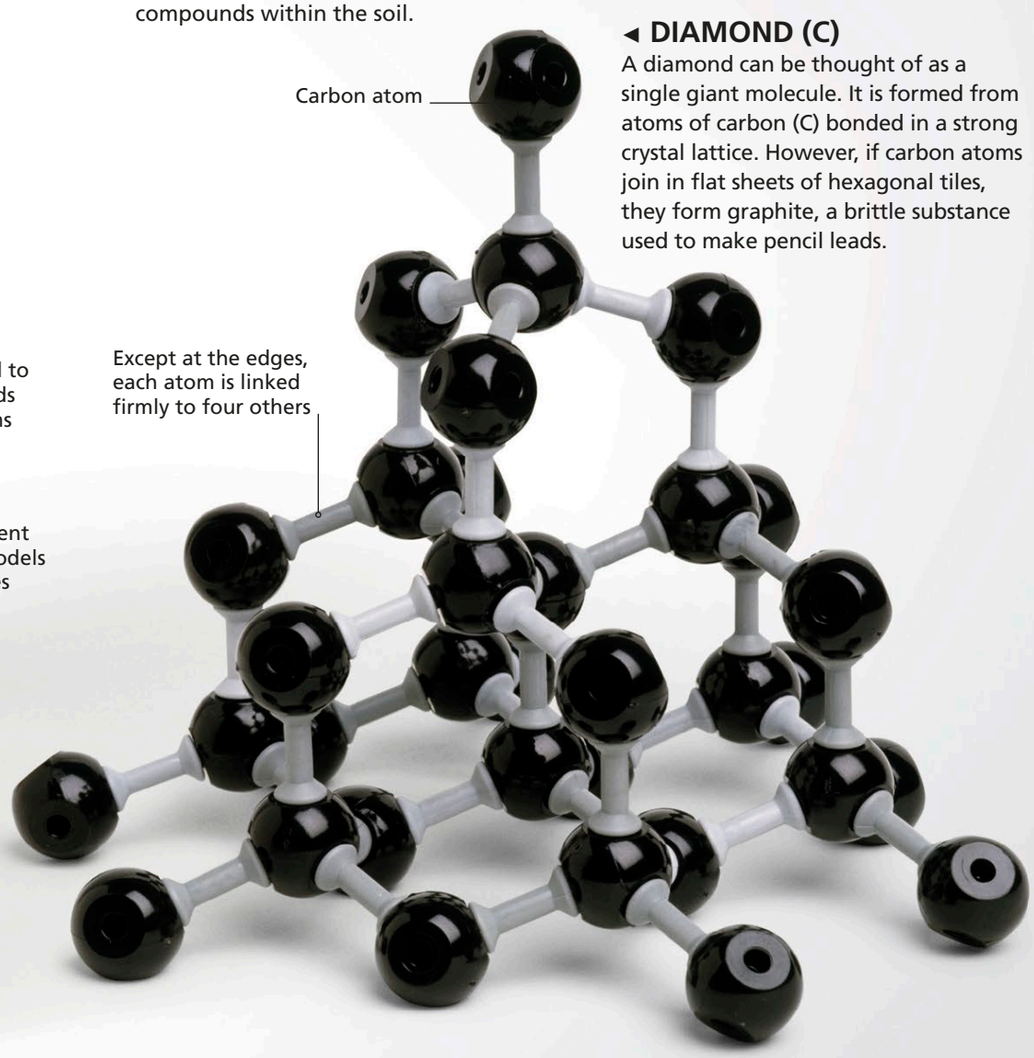
SULFUR (S_8)

Eight atoms of sulfur (S) bond together in a ring to form a sulfur molecule. Most nonmetal elements are gases at room temperature, but sulfur is a brittle, yellow solid.



▲ AMMONIA (NH_3)

The colorless gas ammonia is made up of one nitrogen (N) atom bonded to three hydrogen (H) atoms. Plants get the nitrogen they need to grow from ammonia and other nitrogen compounds within the soil.



◂ DIAMOND (C)

A diamond can be thought of as a single giant molecule. It is formed from atoms of carbon (C) bonded in a strong crystal lattice. However, if carbon atoms join in flat sheets of hexagonal tiles, they form graphite, a brittle substance used to make pencil leads.

ACIDS AND BASES

An acid is a substance that produces positively charged particles of hydrogen, called hydrogen ions, when dissolved in water. The more hydrogen ions an acid contains, the stronger the acid is. A base is the chemical opposite of an acid. Bases produce negatively charged particles in water, called hydroxide ions. The more hydroxide ions a base contains, the stronger it is. Bases that dissolve in water are called alkalis.

◄ CITRIC ACID

The sharp taste in citrus fruit such as lemons and grapefruit is due to the citric acid they contain. Citric acid is often artificially added to manufactured foods and drinks to give a tangy sensation that tastes refreshing.

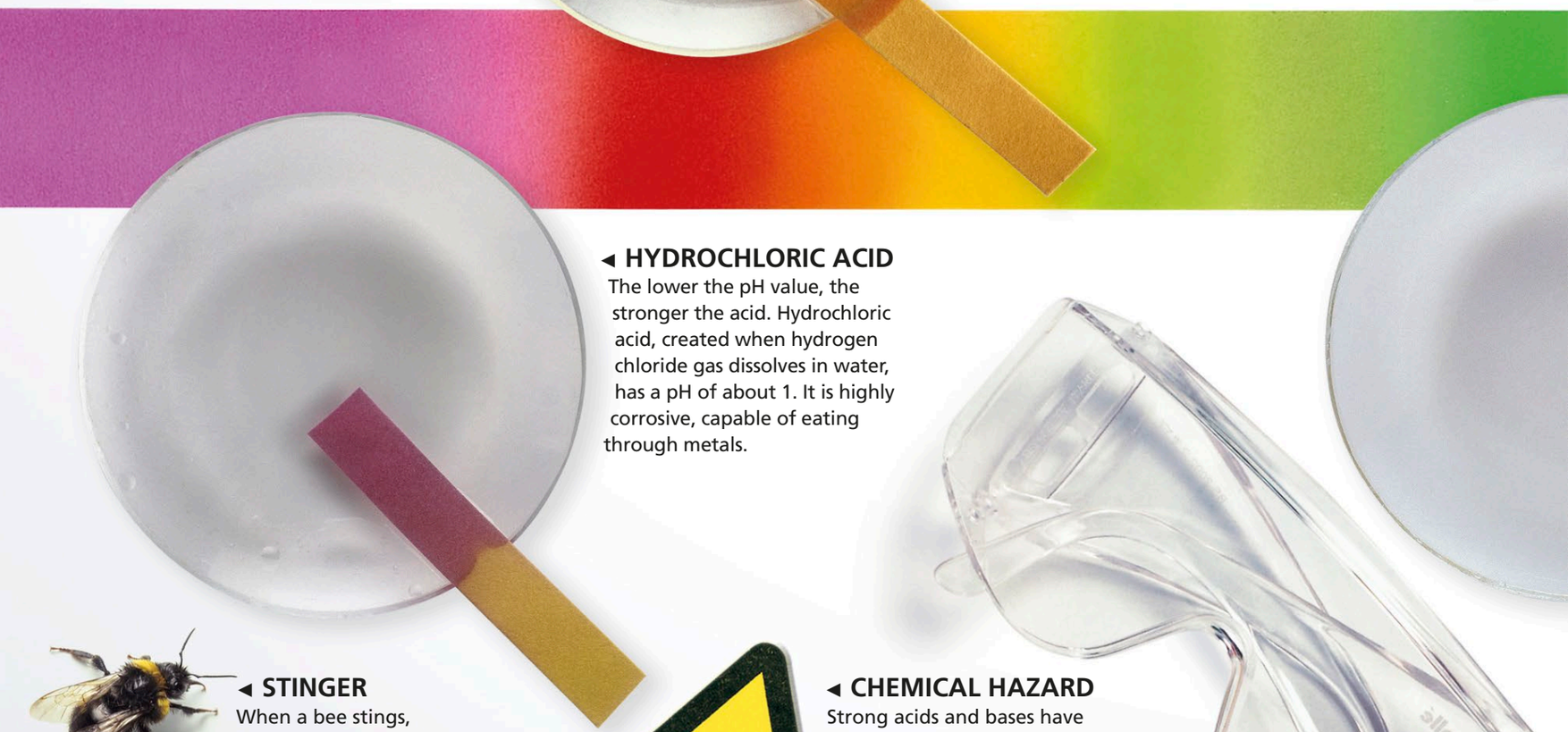
INDICATOR PAPER ▼

When a strip of indicator paper is dipped into a liquid, the paper changes color. The color can be compared to a pH scale to find out the acidity of the solution. pH stands for "potential of hydrogen" and measures how many hydrogen ions the solution contains.

Vinegar is made when bacteria convert the ethanol in alcohol into acetic acid

◄ VINEGAR

The sour taste of vinegar comes from the acetic acid it contains. Every step on the pH scale is 10 times less acidic than the previous step, so acetic acid with a pH of 4 is 1,000 times less acidic than hydrochloric acid.



◄ HYDROCHLORIC ACID

The lower the pH value, the stronger the acid. Hydrochloric acid, created when hydrogen chloride gas dissolves in water, has a pH of about 1. It is highly corrosive, capable of eating through metals.

◄ STINGER

When a bee stings, it injects a mild acid into a person's flesh, which causes a stinging sensation. Washing the sting with alkaline soap may relieve the pain by neutralizing the acid.

◄ CHEMICAL HAZARD

Strong acids and bases have to be stored in containers that will not be corroded by the chemical within. These containers are labeled with chemical hazard symbols that show the potential dangers.

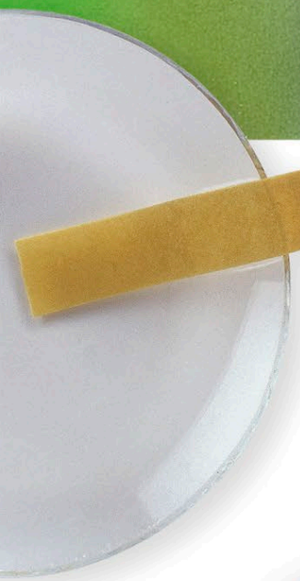
All bases tend to feel slippery like soap

LIQUID SOAP ▸

Soap is a weak base. It is made by combining a weak acid with a strong base, making it only mildly alkaline with a pH of about 8. An indicator paper dipped into liquid soap turns blue.

LIMESTONE ▸

Calcium carbonate, or limestone, is a type of rock formed from the remains of dead sea creatures over millions of years. It is an important base, which is quarried and crushed to make fertilizers, paints, ceramics, and cement.



◂ WATER

Pure water is neither acid nor alkali, but neutral, with a pH of 7. Rainwater is slightly acidic, with a pH of 5 to 6, while seawater is slightly alkaline, with a pH of between 8 and 9.

CLEANING FLUID ▸

The strongest bases have a pH of 14 or more. Alkaline solutions with a high pH are used as cleaning materials as they dissolve fats. Cleaning fluids such as bleach and caustic soda have a pH of around 10.

The pH of tap water is usually between 6 and 8 depending on the gases and minerals that are dissolved in it

HYDRANGEAS ▸

The hydrangea shrub produces different colored flowers depending on the acidity of the soil. On acid soils, it produces blue flowers, on alkaline soils, it produces pink or purple flowers, and on neutral soils, it has creamy white blooms.

CHEMICAL REACTIONS

The atoms within a molecule are held together with links called chemical bonds. In a chemical reaction, the bonds between a molecule's atoms break, and the atoms bond in a different way to form new molecules. In some reactions, elements combine to create a compound. In others, compounds break down into elements or simpler compounds. All the atoms from the original substance exist in the changed substance but in different places.

❶ REACTION

When vinegar (acetic acid) and chalk (calcium carbonate) are mixed, a chemical reaction takes place. The acidic vinegar breaks down the chalk to release carbon and oxygen as bubbles of carbon dioxide. The starting materials in a chemical reaction are called reactants. The materials that exist after are called products.

❷ DISPLACEMENT

In a displacement reaction, the metal that forms part of a compound is removed and replaced by another metal. When a coil of copper is dipped into a clear solution of silver nitrate, the copper displaces the silver from the solution to form a blue solution of copper nitrate and needles of solid metal silver.

❸ BURNING

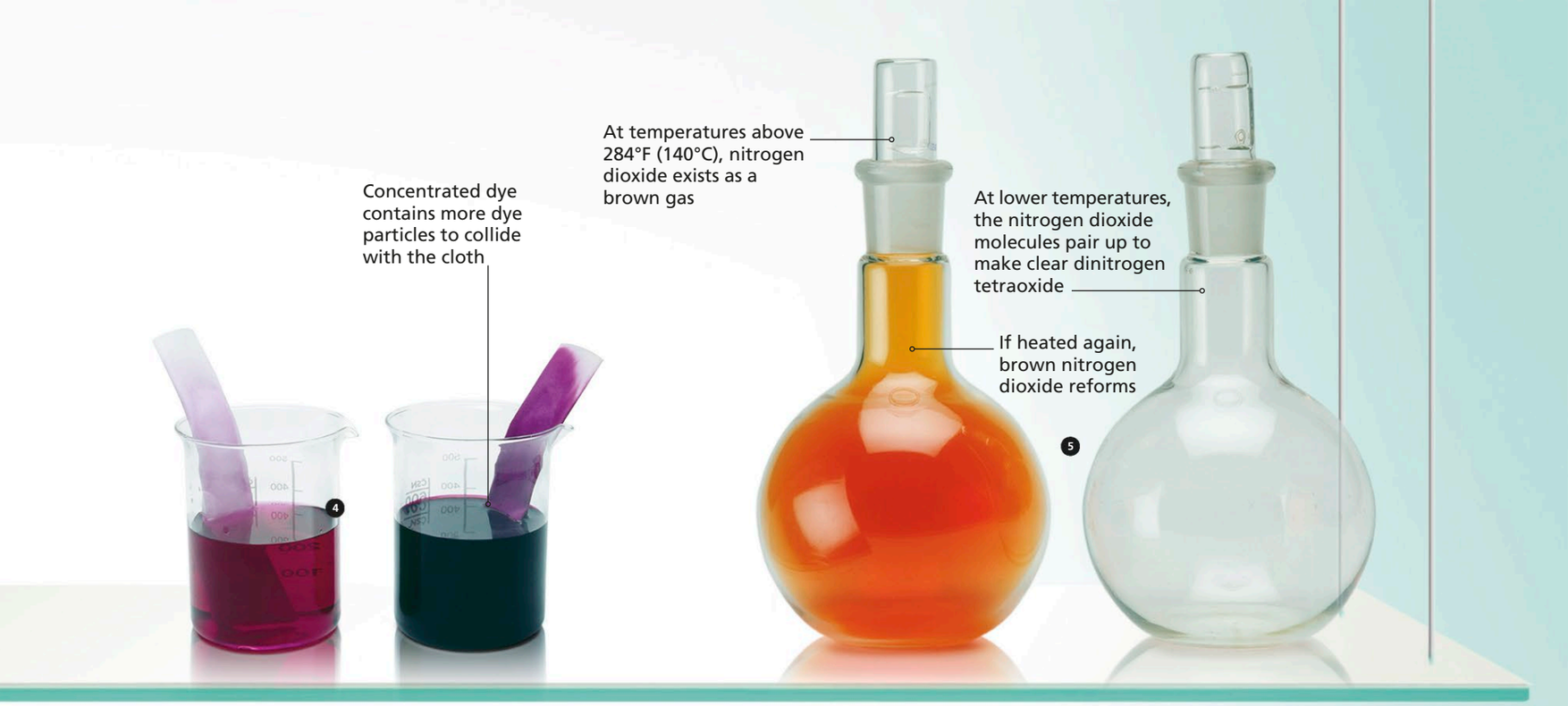
When the wick of a candle burns, it is reacting with oxygen in the air to produce ash and smoke. The burning also produces energy in the form of heat and light. In all reactions, energy is used up when bonds between atoms break, and energy is released as new bonds are made.

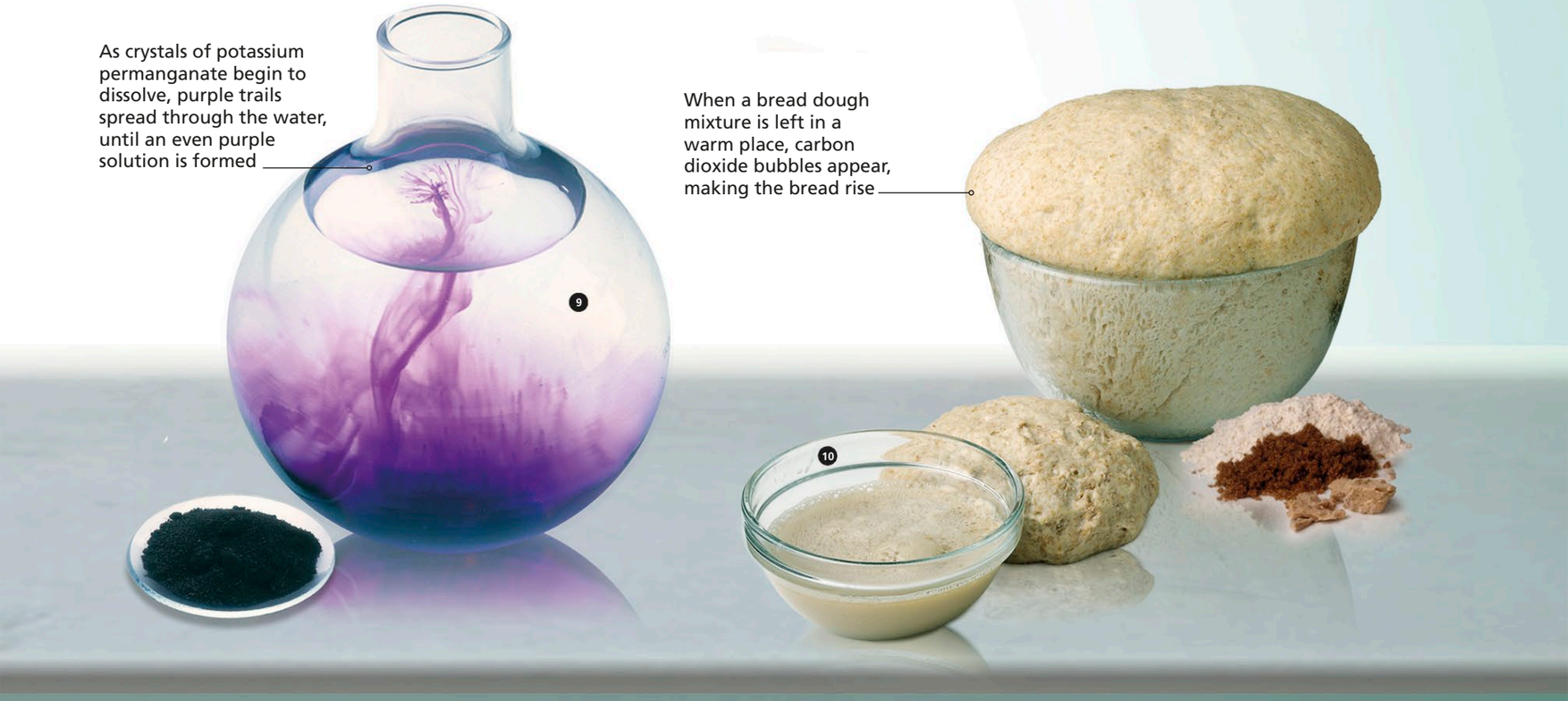
❹ REACTION RATES

The rate of a chemical reaction is affected by factors such as temperature, pressure, light, surface area, and concentration. It is possible to change the rate of a reaction by varying one of these factors. For example, increasing the concentration of dye in a solution will dye the material more quickly.

❺ REVERSIBLE

A few reactions are reversible. The molecules created by the reaction can be reformed into the original materials. The initial reaction is called the forward reaction, and the reverse is the backward reaction. Dinitrogen tetraoxide breaks down into nitrogen dioxide when heated but reverts when cooled.





❻ APPLYING HEAT

When a mixture of yellow powder sulfur and silver-gray iron filings is heated to a high temperature, a chemical reaction takes place, and iron sulfide is formed. Without heat, the substances would not react with each other. Heat speeds up most reactions, and cold slows reactions down.

❼ EXOTHERMIC

Thermite is a mixture of aluminum and iron oxide. When it is ignited at a high temperature, there is an explosion, as the chemical reaction produces a sudden release of energy in the form of light, heat, and noise. Reactions that produce heat are known as exothermic reactions.

❽ OXIDATION

Some chemical reactions happen around us naturally. One of the most common reactions is oxidation—when substances gain oxygen. Oxidation is happening when metals rust, when wood burns, and when we breathe. In all these reactions, substances are reacting with oxygen from the air.

❾ SOLUTIONS

A solution is a mixture in which the molecules are mixed so evenly and completely that it seems like a single substance. However, in a solution, a chemical reaction has not taken place. Neither the solute (the substance being dissolved) nor the solvent (the substance that it is dissolved in) have changed.

❿ CATALYST

A catalyst is a molecule that helps bring about and speed up a chemical reaction but does not change itself during the reaction. Natural catalysts are called enzymes. Bread dough rises because enzymes in yeast cause a reaction that produces bubbles of carbon dioxide when it is mixed with water and sugars.

STATES OF MATTER

Everything you can smell, touch, or taste is made from matter, including living things such as yourself and nonliving things such as this book. Matter is made up of atoms, and anything that is not made of matter is energy. Heat, light, and sound are forms of energy. You cannot smell, touch, or taste energy, and it is not made from atoms. All matter on Earth exists in one of three states: solid, liquid, or gas.

❶ SOLID

A solid, such as this ice sculpture, has a fixed volume and a shape that is not easy to change. Strong links hold atoms together and do not allow them to move around, as they can in a liquid and in a gas. The atoms in most solids are arranged in regular patterns that form three-dimensional shapes, such as cubes and prisms, called crystals.

Unlike most substances, water expands when it freezes (instead of contracting) because its molecules move farther apart when locked into the rigid structure of a solid

❷ GAS

A gas does not have a fixed shape or a fixed volume. It expands to fill all the space around it. Atoms in a gas can move freely in every direction. They whizz around far too fast to ever stick together.

❹ STATE TO STATE

Matter changes from one state to another when it is heated or cooled. Heating melts solids into liquids and boils liquids to form gases. Cooling condenses gases to form liquids and freezes liquids into solids. As matter changes from one state to another, the atoms within it remain the same but become arranged differently.

❺ CHANGING SHAPE

Solids do not always have a fixed shape. Some solids, such as ice or glass, are brittle and will break if you hammer or crush them. Other solids, such as rubber or metals, are malleable and can be hammered, stretched, or squashed into different shapes without breaking.

Most gases are invisible. Even steam cannot be seen until it condenses into a mist of droplets as it mixes with cooler air

❸ LIQUID

A liquid does not have a fixed shape but does have a fixed volume. Its atoms can move past each other, allowing the liquid to flow so that it takes up the shape of its container. Atoms in a liquid are linked together more strongly than in a gas but not as strongly as in a solid.

Even without being brought to boiling point, some of the atoms in liquid water can break free from the surface to become a gas. This is known as evaporation

❸

WATER

Water is a tasteless, odorless liquid. Although it appears to be colorless, in fact it is very pale blue. Each molecule of water is made up of two hydrogen atoms and one oxygen atom, giving it the chemical formula H_2O. Water is Earth's most common compound, found everywhere, from the oceans that cover 71 percent of the planet to each cell of every living organism.

- Unlike most compounds, water can exist in all three states of matter, solid, liquid, and gas, within Earth's normal range of temperatures.

- At sea level, water is liquid between 32 and 212°F (0 and 100°C); but below 32°F (0°C), it solidifies into ice; and above 212°F (100°C), it becomes gaseous water vapor.

- Unlike most other substances, water is denser when it is liquid than when it is solid—that is why ice floats on the top of water instead of sinking.

- When water freezes into ice, it expands by 9 percent of its volume with a force that can burst pipes and split rock.

- Earth is the only place in the solar system where conditions allow water to exist in liquid form at the surface. Some liquid water exists under the surface of the moons of Jupiter and Saturn.

- Water is essential for life, so astronomers look for it when searching for life on other planets.

- The body of an average adult man contains more than 70 pints (40 liters) of water.

- You need about 4 pints (2 liters) of water every day to keep healthy.

- About 30 percent of the world's population do not have clean, safe running water at home.

- Water is not a resource that can be used up like oil. Water evaporates into the air, forms clouds, and falls back to Earth as rain. In areas of Earth that receive little rainfall, water can be a scarce resource.

WATER first incarnation is an art installation by British artist Sean Rogg. He collected water bottles from all over the world.

MATERIALS

Almost everything around us is made from some sort of material. Each has different properties, such as strength or flexibility, which makes it useful for making particular products. Some materials, such as wool or stone, grow or occur naturally. Synthetic materials are manufactured. Composite materials combine the properties of two or more materials to achieve the best possible product.

❶ SILK

This natural fiber is made from the cocoon of the silkworm. Each cocoon may produce 2 miles (3 km) of silk. Silk can be woven into an extremely fine fabric and is prized for its texture and its shiny appearance.

❷ CONCRETE

Concrete is made by mixing sand, gravel, cement, and water. It is a liquid when freshly made, so it can be poured into a mold, where it sets to form an extremely hard and durable material.

❸ KEVLAR

A light, flexible, synthetic material, Kevlar is used for protective clothing, such as bulletproof vests. Kevlar molecules are arranged in long chains with strong bonds between them, which makes Kevlar five times stronger than steel.

❹ WOOL

This natural material comes from the fleece of sheep. The structure of its fibers means wool has a tendency to shrink, so it is often mixed with synthetic fibers to make easy-care fabrics.

❺ CARBON COMPOSITES

These materials are strong and light and can be turned into complex shapes, such as sports equipment. They are made from the carbon byproducts of coal, oil, and natural gas.

❾ LYCRA

Synthetic fabrics are designed to have better properties than natural materials, such as cotton. Lycra is a stretchy fabric that keeps its original shape, making it perfect for sports clothes.

❷ CERAMIC

Ceramic materials are made by heating different types of clay to a high temperature. China, bricks, tiles, cement, and glass are all ceramics. These materials are hard, brittle, and resistant to heat.

❿ RUBBER

Natural rubber is an elastic material made from latex, a milky fluid from the rubber tree. Synthetic rubber is made from petrochemicals. Rubber is used in tires and for waterproofing fabrics.

❸ WOOD

Wood is a strong material compared to its weight and is a good building material. It is also used for furniture and art objects because of its attractive texture. It is referred to as hardwood or softwood, depending on the type of tree it comes from.

⓫ NYLON

Developed in 1938, nylon was the first synthetic fabric. It can be produced in extremely fine threads, is cheap to manufacture, and was first used as a replacement for silk in stockings and parachutes.

❹ COTTON

Cotton is a natural material produced from the long, flexible fibers in the fluffy seedpods of the cotton plant. The fabric is soft, comfortable to wear, and there is no static buildup as there is with some synthetic fabrics.

Wood can be cut, carved, and sanded into shape

Nylon rope lasts longer than one made of natural fibers

Cotton fibers are spun into threads and then woven into fabric

❼ PLASTIC

This group of synthetic materials is made from petrochemicals. They are strong, light, and cheap to make and can be molded or shaped into flexible sheets, films, or fibers.

Hand-carved granite makes a durable kitchen tool

❻ METAL

When heated, metals can be shaped into anything from a paperclip to an aircraft. They are also good conductors of heat and suitable for carrying electricity.

❽ GLASS

This transparent ceramic is made by fusing sand, limestone, and soda at high temperatures, or by recycling old glass. Molten glass can be shaped in many ways, such as into windows, lenses, and threads for optical fibers.

❶❺ STONE

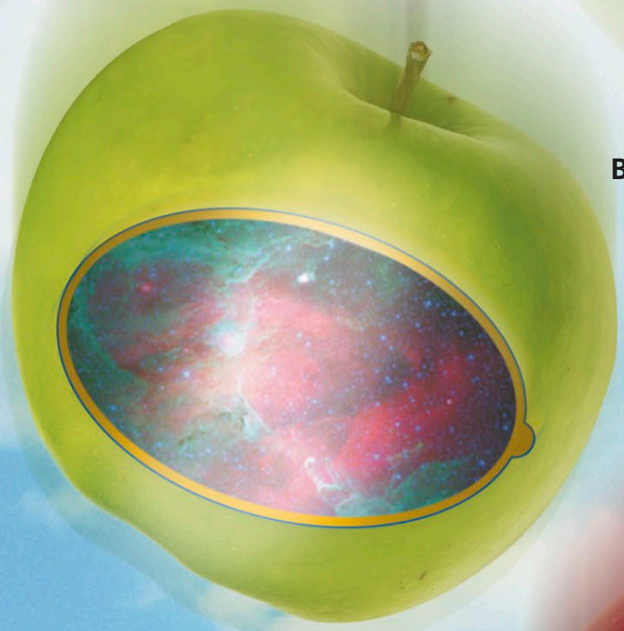
Stone is a natural material quarried from the ground. It is hard and heavy and can withstand great pressure. Stone may be cut using diamond saws or extremely high-pressure jets of water.

GRAVITY

The force of gravity is a force of attraction that exists between all objects with mass, from microscopic atoms to stars and planets. On Earth, gravity can be seen when objects fall to the ground, pulled by an invisible force. In space, the force of gravity keeps the moon in its orbit around Earth, keeps planets in orbit around the stars, and holds huge clusters of stars together as galaxies.

NEWTON'S DISCOVERY

An apple falling from a tree is said to have inspired English scientist Isaac Newton (1642–1727) to explore the force of gravity. He developed a theory stating that every mass attracts every other mass by a force between both masses. The more massive an object is and the nearer it is, the greater its gravitational attraction.

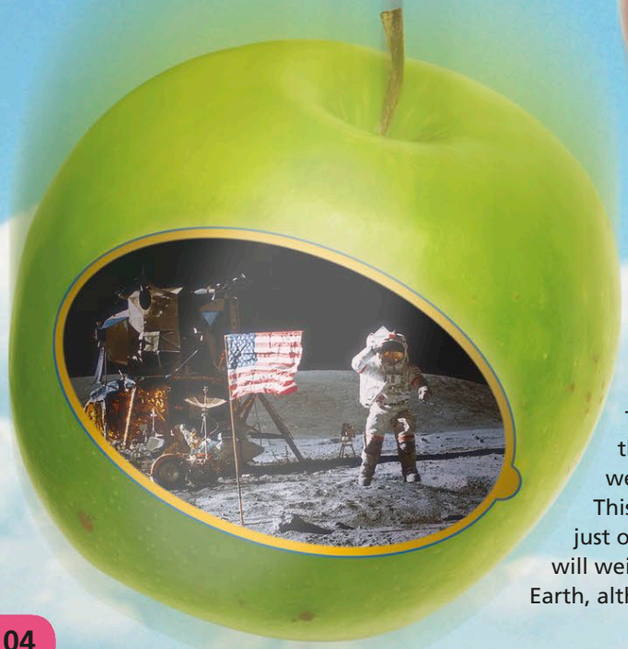


BIRTH OF A STAR

A star is born inside a cloud of dust and gas in space called a nebula. The dust and gas begin to clump together, forming a core. The clump's gravitational attraction increases as its mass increases, dragging in more and more matter. The center, or core, becomes so massive and dense that nuclear fusion begins, and the star begins to shine.

MOON AND TIDES

As the moon orbits Earth, its gravity tugs at the water in the oceans, making a mass of water bulge toward the moon. The force of Earth's spin creates a matching bulge on the other side of Earth. These bulges cause the regular rise and fall of the water level at the sea's edge that we know as tides.



MASS AND WEIGHT

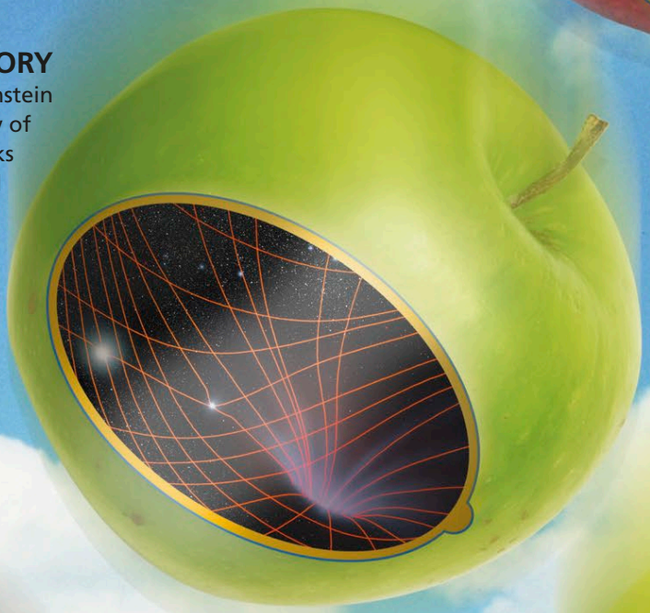
These are not the same. An object's mass is the amount of matter it contains. An object's weight is the force exerted on its mass by gravity. This means that on the moon, where gravity is just one-sixth of Earth's gravity, an astronaut will weigh one-sixth as much as he weighs on Earth, although his mass is the same.

ZERO GRAVITY

In orbit around Earth, astronauts become weightless and float around their spacecraft as if gravity did not exist. In fact, gravity is still pulling the astronauts and their spacecraft toward Earth, but as the spacecraft travels forward, it is also continually "falling" as it follows the curve of Earth. The craft and astronauts are in a state of free fall, but falling without ever reaching the ground.

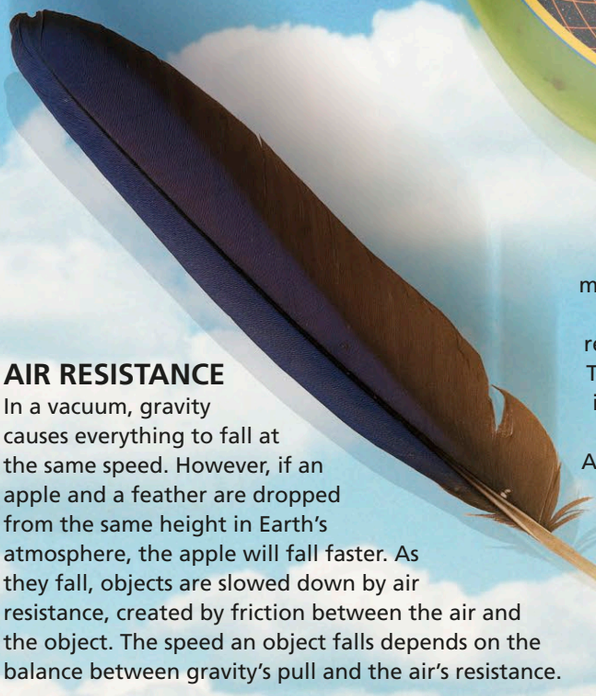
CENTER OF GRAVITY

An object's center of gravity is the point at which it balances. An object with a low center of gravity is more stable—so a sports car is more stable than a double-decker bus. The secret to driving a car on two wheels is to ensure that the center of gravity remains above the wheels—any further over and the car will tip over.



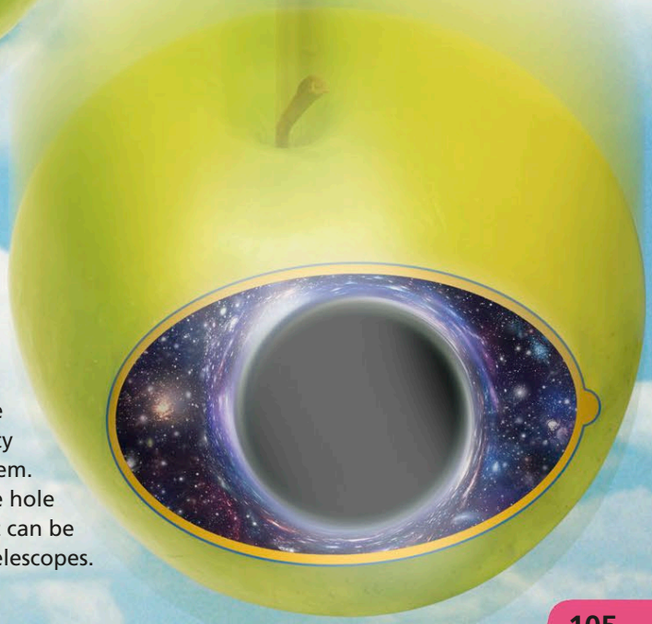
EINSTEIN'S THEORY

German-born scientist Albert Einstein (1879–1955) developed a theory of relativity to explain how gravity works in space. He compared space and time to a sheet of flexible rubber that everything in the universe rests on. Massive objects like stars make a big dip in the rubber. Less massive objects like planets fall into these large dips and so are trapped orbiting stars. The dips create the effect we call gravity.



AIR RESISTANCE

In a vacuum, gravity causes everything to fall at the same speed. However, if an apple and a feather are dropped from the same height in Earth's atmosphere, the apple will fall faster. As they fall, objects are slowed down by air resistance, created by friction between the air and the object. The speed an object falls depends on the balance between gravity's pull and the air's resistance.



BLACK HOLES

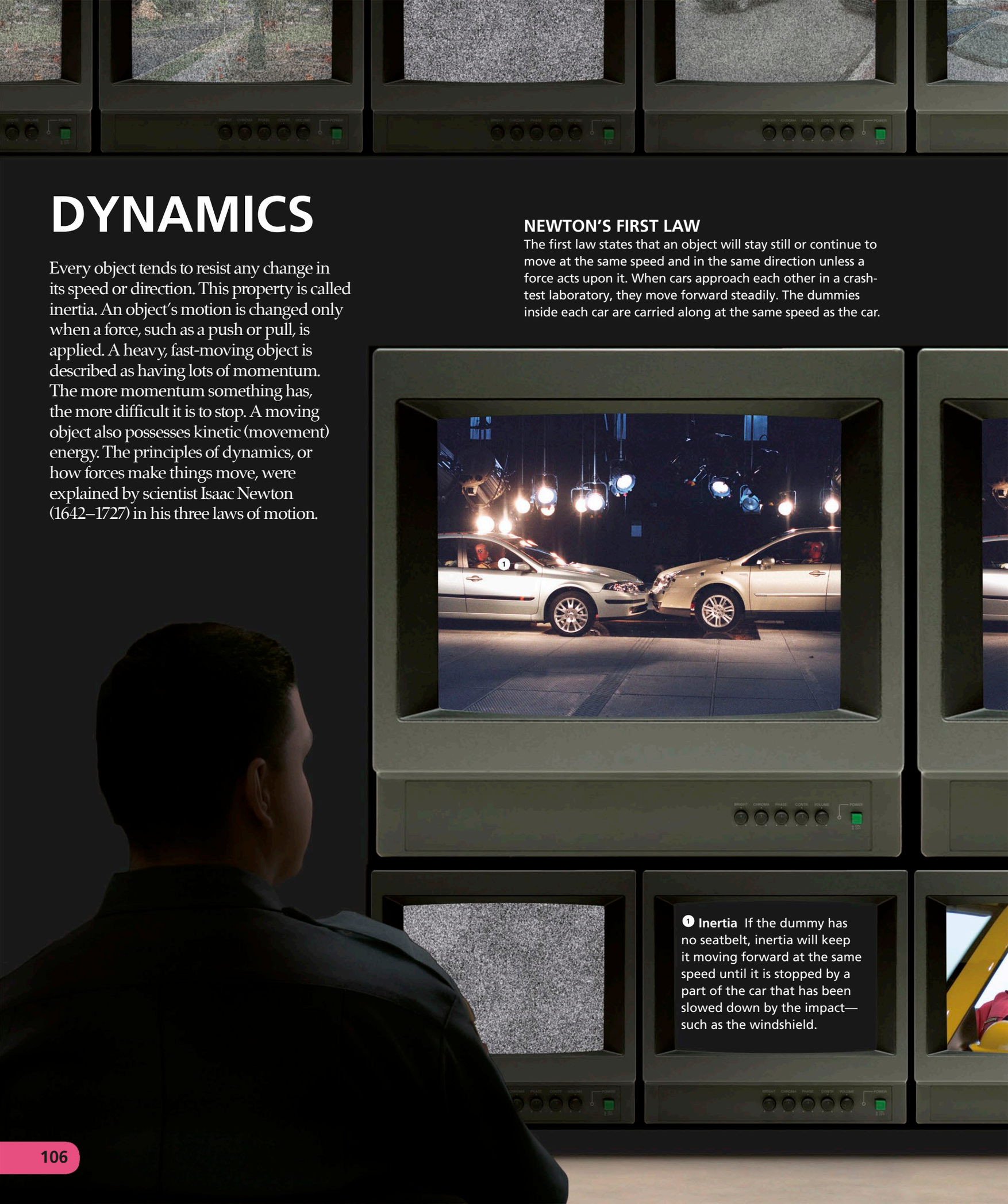
When a massive star dies, its core may collapse. As it shrinks, the core becomes ever denser and forms a region of space called a black hole. The force of gravity in a black hole is so strong that anything entering it is swallowed up, including light. Although invisible, black holes can be identified by the effect their gravity has on everything around them. Material being sucked into the hole heats up, emitting X-rays that can be detected by X-ray telescopes.

DYNAMICS

Every object tends to resist any change in its speed or direction. This property is called inertia. An object's motion is changed only when a force, such as a push or pull, is applied. A heavy, fast-moving object is described as having lots of momentum. The more momentum something has, the more difficult it is to stop. A moving object also possesses kinetic (movement) energy. The principles of dynamics, or how forces make things move, were explained by scientist Isaac Newton (1642–1727) in his three laws of motion.

NEWTON'S FIRST LAW

The first law states that an object will stay still or continue to move at the same speed and in the same direction unless a force acts upon it. When cars approach each other in a crash-test laboratory, they move forward steadily. The dummies inside each car are carried along at the same speed as the car.



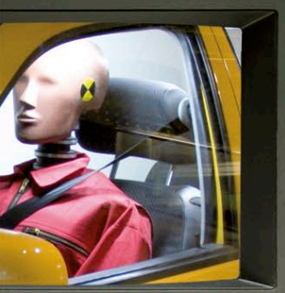
❶ **Inertia** If the dummy has no seatbelt, inertia will keep it moving forward at the same speed until it is stopped by a part of the car that has been slowed down by the impact—such as the windshield.

NEWTON'S SECOND LAW

This states that when a force acts on an object, it makes the object change speed or direction. As the two cars collide, the front of each car exerts a force on the other car, slowing it down. The dummies inside are slowed down as they experience the force of the seatbelt.

NEWTON'S THIRD LAW

The third law of motion says that when a force acts on an object, the object reacts by pulling or pushing back with equal force but in the opposite direction. So it is impossible for one car to push on the other without experiencing a pushback with equal force.



❷ **Collision** When two cars collide, kinetic energy is converted to other forms of energy, such as heat and sound, as the fronts of the cars crumple. This is called an inelastic collision.

❸ **Momentum** If a heavy truck collides with a car, the truck's greater momentum pushes the car along for some distance, but cars of equal weight and speed are halted, since their equal but opposite momenta cancel out.

MAGNETISM

Magnetism is an invisible force that attracts (draws toward itself) or repels (pushes away) certain materials. Any object that can attract or repel magnetic materials is classed as a magnet. The area around a magnet that is influenced by its magnetism is referred to as its magnetic field. It is strongest at the "poles" (usually the ends) of the magnet. Opposite magnetic poles will attract each other, while like magnetic poles repel each other. Planet Earth has its own magnetic field, driven by the molten material that circulates beneath the surface.

❶ MAGNETIC MATERIALS

When an unmagnetized magnetic material is placed in a magnetic field, it becomes a magnet itself, either temporarily or permanently. Materials such as nickel and iron are easily magnetized and demagnetized and are known as soft magnets. Alloys (mixtures) of iron, nickel, and aluminum are difficult to demagnetize and are referred to as hard, or permanent, magnets.

❷ ATTRACTION

Iron filings sprinkled around a magnet will reveal the magnetic force field in action. If you bring two magnets together so that a north pole is facing a south pole, then the filings will bridge the gap, showing attraction.

❸ REPULSION

If you bring two magnets together with their two north poles or two south poles facing, you can feel the pushing force between them as their magnetic fields come into contact and the like poles repel each other.

❹ MAGNETIC STRENGTH

The strength of the attraction that holds all these objects together can also be used in industry. Large cranes with a lifting magnet are used to move tons of scrap metals and old cars and load heavy machine parts.

This MRI scan shows soft tissues as well as bones

Steel pins are attracted by the magnetic force of the lodestone

Iron filings push away because like poles repel

North pole

North pole

North pole

Iron filings join because opposite poles attract

South pole

The red needle on this compass points to the magnetic north pole

❺ LODESTONE

Nearly 3,000 years ago, people discovered that a strange type of rock could attract iron objects. This rock, called lodestone or magnetite, is a form of iron oxide with strong natural magnetism. The first compasses were made from lodestone.

❻ MAGNETIC SCAN

In a magnetic resonance imaging (MRI) scan, a patient is placed in a magnetic field, and radio waves are passed through the body, causing molecules within body tissues to vibrate. Different tissues vibrate in different ways, allowing each part to be seen clearly.

❼ MAGNETIC EARTH

Electric currents circulating inside Earth as the planet rotates cause it to act like a giant magnet, with a magnetic field that extends thousands of miles into space. Earth has magnetic poles, which are near, but not the same as, the geographic North and South Poles.

❽ COMPASS

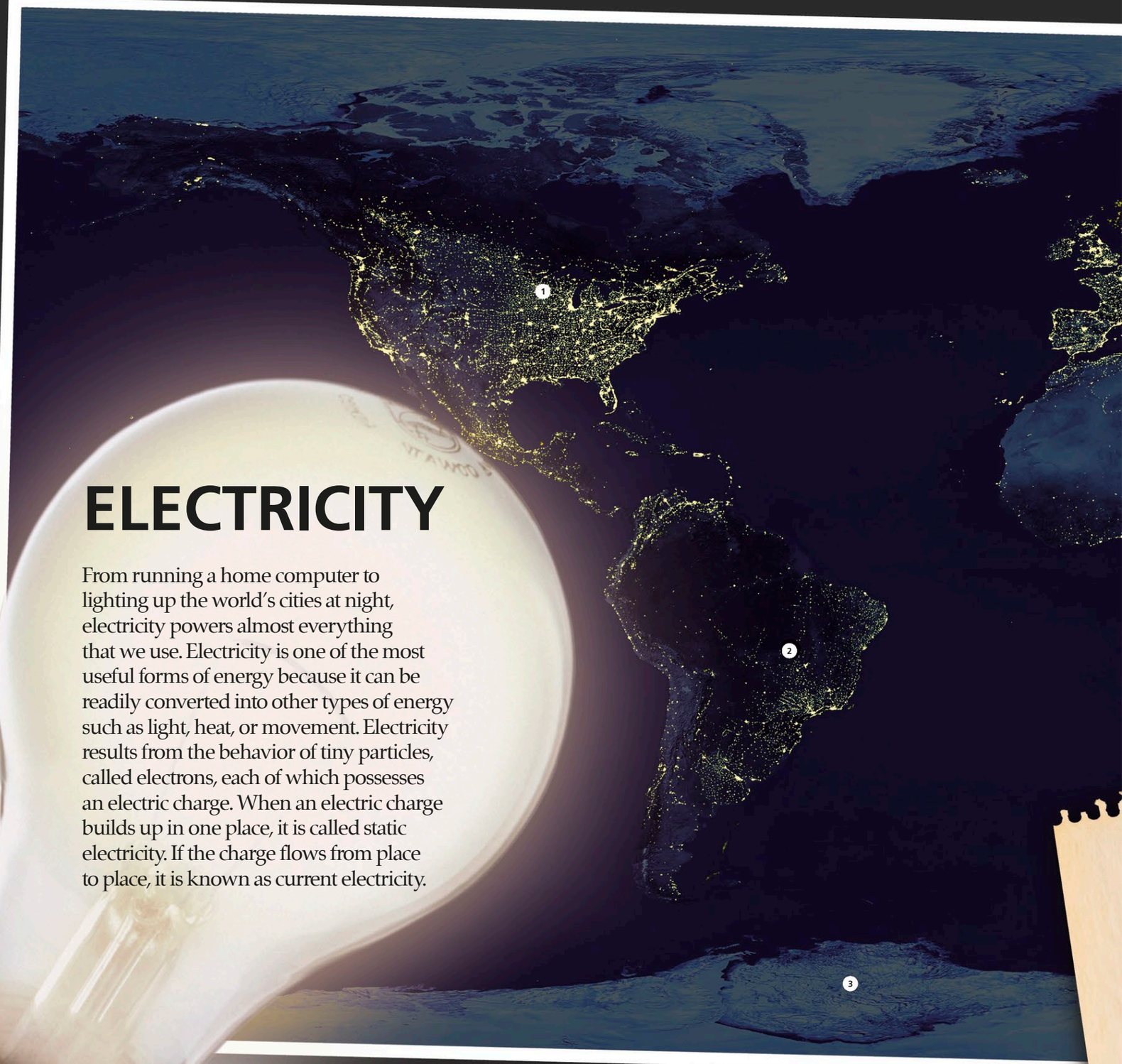
In use from around the 12th century, a compass contains a magnetic needle, which is free to rotate on a pivot. The compass needle will always align itself with Earth's magnetic field so that its needle points toward the magnetic north pole.

• Electricity is generated when coils of wire are rotated in a magnetic field. This forces electrons along the wire to form an electric current.

• In power plants, the force to rotate the coils is provided by water power (hydroelectricity), or by steam heated by oil, coal, gas, or the process of nuclear fission.

• A current flows only if it has a circuit to travel around. A current needs a conductor to flow through, something to power, and, usually, an energy source to drive the current.

• All conductors have a certain resistance to the flow of an electric current. When a conductor resists the current, the electrical energy is turned into heat.



ELECTRICITY

From running a home computer to lighting up the world's cities at night, electricity powers almost everything that we use. Electricity is one of the most useful forms of energy because it can be readily converted into other types of energy such as light, heat, or movement. Electricity results from the behavior of tiny particles, called electrons, each of which possesses an electric charge. When an electric charge builds up in one place, it is called static electricity. If the charge flows from place to place, it is known as current electricity.

• A flash of lightning is a giant spark of electricity driven by static electricity (charge) that builds up inside a cloud from a collision of ice crystals and water droplets.

• Static electricity also occurs when you comb your hair or take off a synthetic sweater. It is caused by two things rubbing together and creating a charge.

• The human body is full of electricity. The 100 billion nerve cells in each person's brain work by sending messages in bursts of electricity (impulses).

• Materials with electrons that cannot move are unable to conduct electricity and are known as insulators. Electric wire is insulated with plastic or rubber.

• Electricity leaves power plants through metal cables on tall towers. The power is sent out at a much higher voltage than is used in most homes.

• Before arriving in a city, the voltage is reduced by a transformer at a substation. It then travels across the city in cables under the streets.

• In some earthquake-prone cities, such as Tokyo, Japan, electricity is carried in overhead cables. Underground cables would be too prone to earthquake damage.

1 North America The US has less than 5 percent of the world's population but uses more than 15 percent of the world's electricity, most of it generated in coal-fired power stations. In Canada, hydroelectric generation accounts for more than half of all electricity generated.

2 South America Some countries in this continent produce electricity using ethanol, a renewable "green" fuel made from the byproducts of sugar cane.

3 Antarctica The only people who live here are scientific researchers. Their electricity is mostly provided by diesel-powered generators but also increasingly from wind and solar power.

4 Europe A variety of different sources are used to generate electricity in Europe, including nuclear power. France relies on nuclear power stations for more than three-quarters of its electricity.

5 Africa Less than half of the 1.3 billion people living in Africa have access to electricity, and in many countries, people suffer from frequent power outages. Solar and geothermal generation holds great promise for the future.

6 Asia In recent years, China, Japan, and India have accounted for much of the increase in electricity generation and use. China relies on coal-fired power stations but is rapidly increasing its use of solar power.

7 Australia Australia relies on coal-fired power stations for about half of its electricity, but in New Zealand 97 percent is generated by hydroelectric power.

NIGHT LIGHT
This image was compiled from pictures taken by a military weather satellite. It shows how light from the world's cities is visible from space.

ELECTROMAGNETIC SPECTRUM

Energy spreads in waves of electromagnetic radiation, like the ripples on a pond. It travels through space at the speed of light, around 185,000 miles/sec (300,000 km/sec). Although energy always travels through space at the same speed, its wavelength (the distance between any two peaks or troughs of the waves) can vary. Short waves, such as X-rays, carry high amounts of energy that can penetrate the human body, while longer, lower energy waves, such as light, cannot. Aside from visible light, all electromagnetic waves are invisible. Together, these waves make up a continuous band of energy known as the electromagnetic spectrum.

GAMMA RAYS

Gamma rays are produced by radioactivity, such as a nuclear explosion. They have a short wavelength and carry large amounts of energy. They are very harmful to humans but are used to treat cancer by killing damaged cells.

X-RAYS

These high-energy waves can pass through materials such as flesh and suitcase plastic, but not through bone or metal objects. This makes them a valuable tool for examining bones in hospitals and searching for weapons in airports.

ULTRAVIOLET RAYS

With a slightly shorter wavelength than visible violet light, ultraviolet rays also carry more energy than visible light. Ultraviolet rays emitted by the sun and tanning beds can damage skin not protected by sunblock, causing sunburn.

VISIBLE LIGHT

The sun emits most of its energy as visible light, which can be split into the colors of the rainbow. Earth's atmosphere allows visible light through while blocking more harmful wavelengths. Visible light is vital for life. Without it, plants could not grow.

WAVELENGTHS

The difference between wavelengths at either end of the electromagnetic spectrum is immense. The wavelength of gamma rays is only a fraction of the size of an atom, while radio waves at the opposite end of the spectrum can be thousands of miles long.

INFRARED RAYS

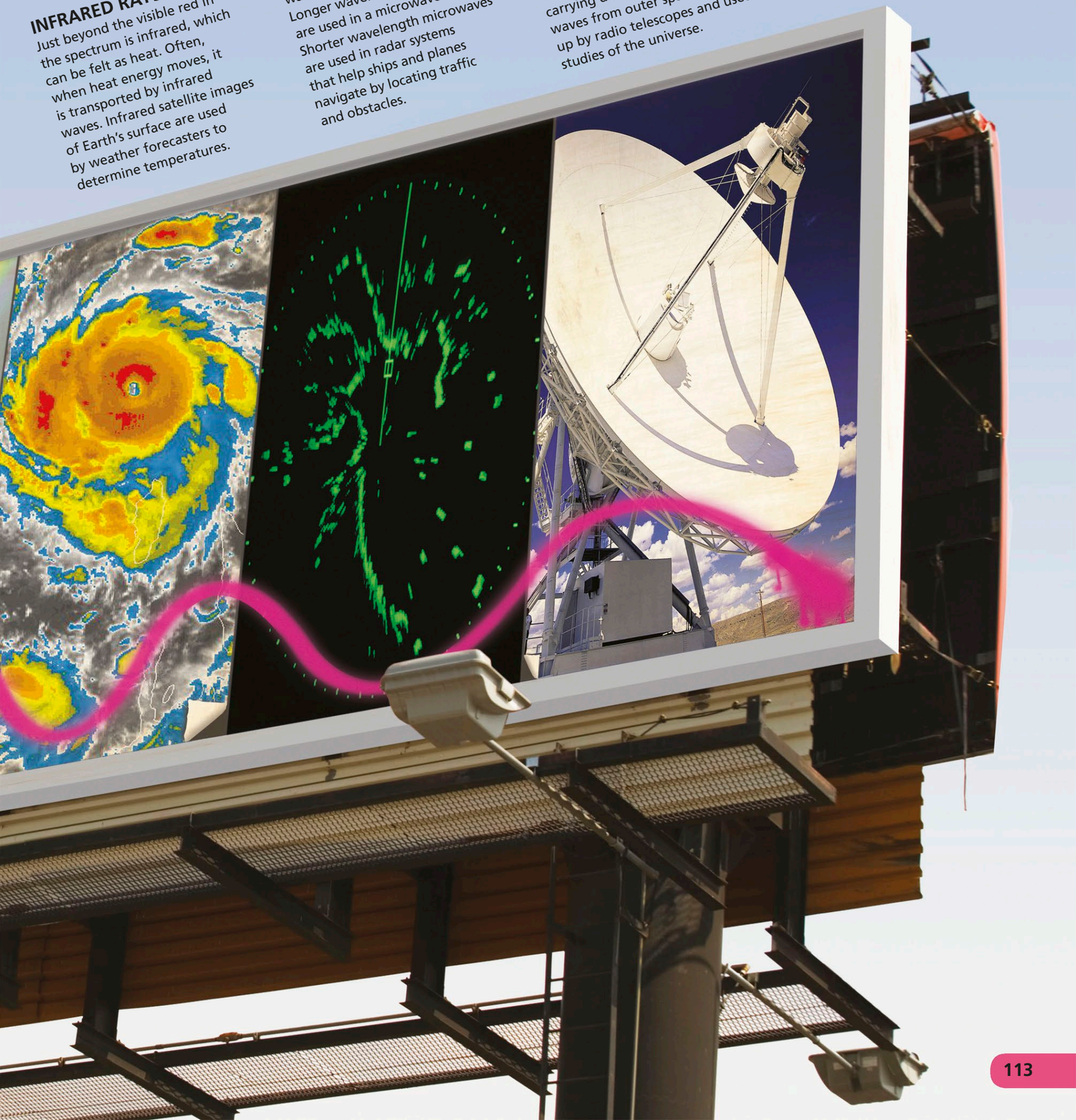
Just beyond the visible red in the spectrum is infrared, which can be felt as heat. Often, when heat energy moves, it is transported by infrared waves. Infrared satellite images of Earth's surface are used by weather forecasters to determine temperatures.

MICROWAVES

These have much longer wavelengths than visible light. Longer wavelength microwaves are used in a microwave oven. Shorter wavelength microwaves are used in radar systems that help ships and planes navigate by locating traffic and obstacles.

RADIO WAVES

These are the longest in the spectrum. Many forms of communication, such as TV, cell phones, and radio, use radio waves, with different wavelengths carrying different signals. Radio waves from outer space are picked up by radio telescopes and used in studies of the universe.



COLOR

Light is the visible part of the electromagnetic spectrum. We see different wavelengths of light as different colors. The surfaces of objects absorb some wavelengths and reflect others. A white object looks white because it reflects all the wavelengths that fall on it. A black object absorbs all the wavelengths, so it appears dark.

VIOLET

Light at the violet end of the visible spectrum has a shorter wavelength and higher frequency than light at the red end of the spectrum.

SYMBOLISM

We use colors as symbols to represent different ideas in culture and religion. However, the meaning of colors may vary. For example, in some cultures, brides wear red, whereas in others, they wear white.

Gifts of money are given in red packets at Chinese New Year, because red is the color of luck

Red food packaging is believed to cause feelings of hunger

COMPLEMENTARY COLORS

If the colors of the spectrum are arranged in order on a color wheel, colors located opposite each other, such as orange and blue, are called complementary colors. When complementary colors are presented side by side, they appear at their brightest.

Yellow New York taxis are easy to spot in the distance

REAL COLORS

The light from most objects is made up of a range of wavelengths. An object that looks yellow might reflect 80 percent of the light at the yellow wavelength but also smaller amounts of other color wavelengths.

COLOR BLINDNESS

Our ability to detect colors depends on cells on the eye's retina, which are sensitive to specific wavelengths of light. The cells that detect certain parts of the spectrum are missing or inactive in a color-blind person.

INTENSITY

On a sunny day, things appear colorful because our eyes can see differences in the wavelengths of light. On a dark day, less light enters the eyes, so we cannot distinguish wavelengths as easily, and colors look dull.

A yellow object absorbs all the wavelengths except yellow, which it reflects back to our eyes. The band of visible colors that make up light is known as the spectrum. Each shade blends into the next, but we usually divide the spectrum into seven colors: red, orange, yellow, green, blue, indigo, and violet.

SPLITTING WHITE LIGHT

When white light passes through a block of glass called a prism, different wavelengths refract (bend) different amounts, so the light splits showing the colors of the spectrum. When light passes through raindrops, this effect creates a rainbow.

Green plants contain a green pigment called chlorophyll

MACHINES

Simple machines make it easier for people to perform tasks, such as lifting or pulling, which would be difficult to do with muscle strength alone. There are six types of simple machines: the wheel, the screw, the lever, the pulley, the inclined plane, and the wedge. These machines change a force into a bigger or smaller force or alter the direction in which a force acts. The most basic tools, such as crowbars or spades, are simple machines.

❶ WHEEL (GEAR)

Gears are toothed wheels that mesh and turn together, changing the strength, speed, or direction of a force. A force on the axle of a small gear driving a large gear will lead to a bigger turning force on the axle of the large gear.

❷ SCREW

The spiral thread on a screw changes a turning force into a much stronger up or down force. The screw has to be turned many times to create just a small up or down movement.

❸ LEVER

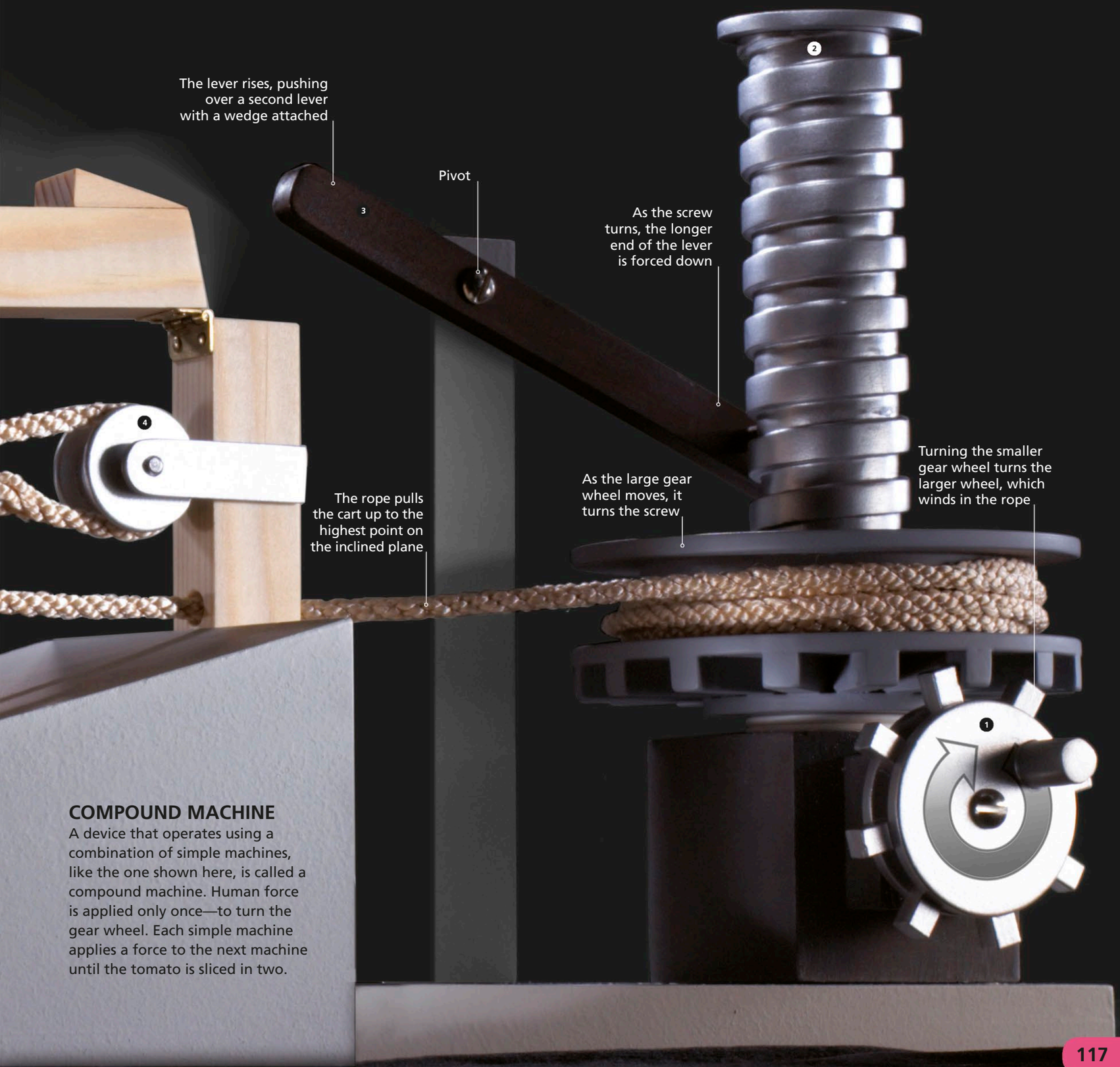
Most levers magnify the force applied to them, making it easier to move a load. A lever turns around a fixed point called a pivot. The farther from the pivot the force is applied, the easier it is to move the load.

❹ PULLEY
A pulley is a rope looped around a wheel to make a load easier to lift or move. The more ropes and wheels are used, the less force is needed to lift the load but the farther the rope has to be pulled.

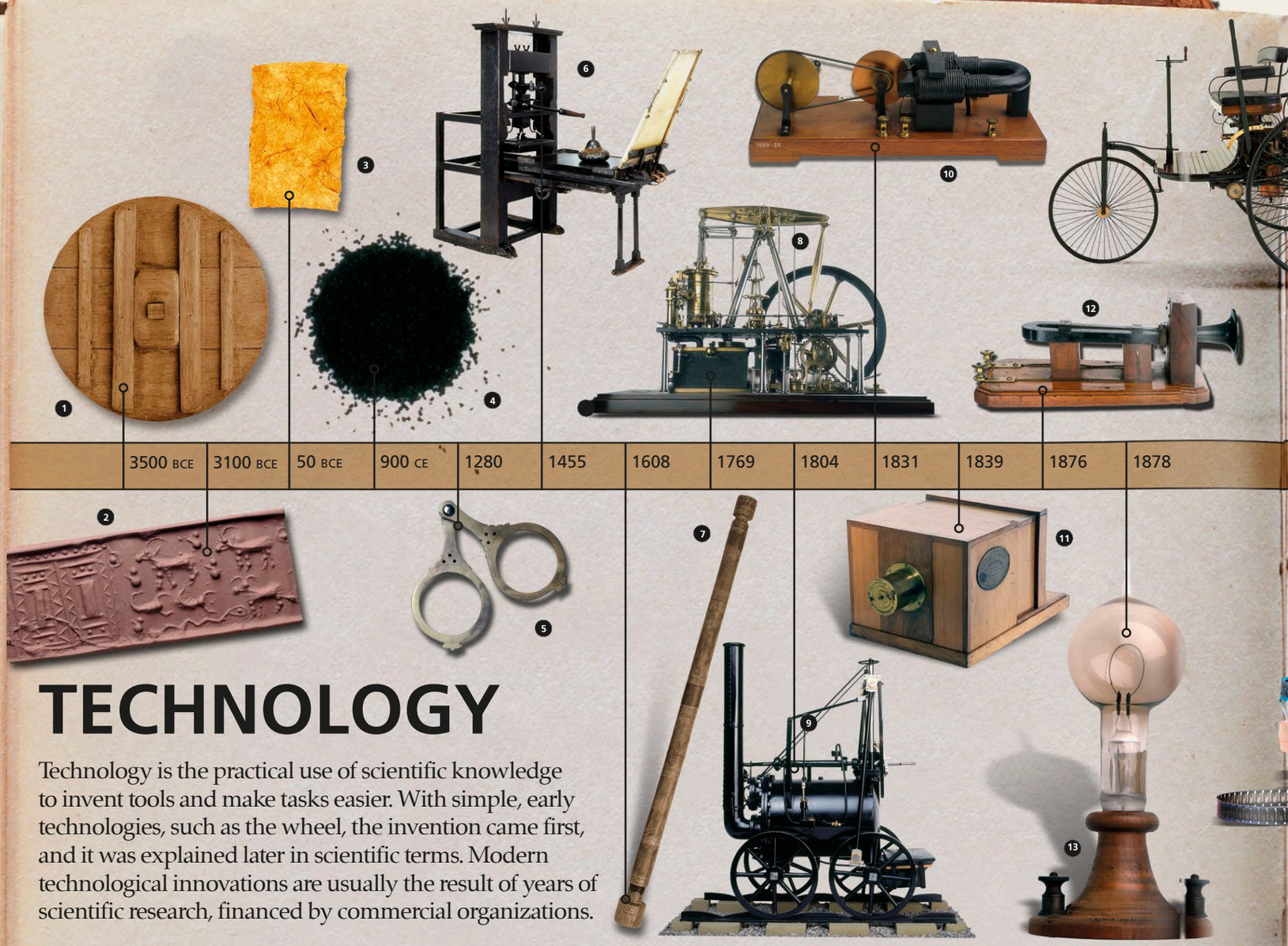
❺ INCLINED PLANE
This is a flat surface with ends at different heights. Moving an object up an inclined plane reduces the amount of force needed to lift it up but increases the distance it has to travel.

❻ WEDGE
This triangular object is used as a blade to split something or inserted under an object to lift it. As a downward force is exerted on the wedge, its widening shape produces a sideways force on the object.

❼ CART WHEELS
These wheels allow the cart to move smoothly up the ramp. Unlike gear wheels (1), these are not classed as a machine, because they do not change the size of the force applied to them to help do something.



COMPOUND MACHINE
A device that operates using a combination of simple machines, like the one shown here, is called a compound machine. Human force is applied only once—to turn the gear wheel. Each simple machine applies a force to the next machine until the tomato is sliced in two.



TECHNOLOGY

Technology is the practical use of scientific knowledge to invent tools and make tasks easier. With simple, early technologies, such as the wheel, the invention came first, and it was explained later in scientific terms. Modern technological innovations are usually the result of years of scientific research, financed by commercial organizations.

❶ **Wheel** The first wheels were used in Mesopotamia (now Iraq). They were made from planks nailed together to form a circle.

❷ **Writing** In Mesopotamia, records of accounts and lists of goods were scratched on clay tablets, and people used seals with raised images to mark personal property.

❸ **Paper** The process of papermaking was also invented in China. Rags and plant fibers were mixed with water, beaten to a pulp, then spread out to dry into a sheet.

❹ **Gunpowder** The explosive properties of gunpowder were first used by the Chinese to produce fireworks and dramatic bangs to frighten enemies rather than kill them.

❺ **Eyeglasses** In the 11th century, the Chinese found that curved pieces of glass (lenses) could bend light. Eyeglasses were not produced until almost 300 years later.

❻ **Printing** The printing press developed by Johannes Gutenberg used a system of movable type—individual metal letters made quickly and cheaply—allowing books to be mass-produced for the first time.

❼ **Telescope** The first telescope was a refracting telescope that used two lenses to focus light from distant objects.

❽ **Steam engine** James Watt's rotary steam engine provided the power for the factories and mines of the Industrial Revolution by converting the energy in steam into motion.

❾ **Railroad locomotive** The first railroad locomotive used a high-pressure steam engine to move a train along rails.

❿ **Electric generator** Michael Faraday invented the first electric motor, which used electricity to produce motion. He then reversed this process, using motion to produce electricity, thus inventing the electric generator.

⓫ **Photography** The first practical photographic process was invented by Louis Daguerre. Known as the Daguerreotype, it used a copper plate coated with silver and light-sensitive chemicals to capture the image.

⓬ **Telephone** Alexander Graham Bell invented the telephone after discovering that voice vibrations could be converted to electrical signals, sent along a wire, and converted back into sound vibrations at the other end.

⓭ **Light bulb** Joseph Swan and Thomas Edison simultaneously came up with the light bulb, which works by causing a metal filament to glow when an electric current passes through it.

⓮ **Gasoline-engine automobile** The first automobile with an internal combustion engine powered by gasoline had a U-shaped steel frame and three wheels.

⓯ **Cinema** Brothers Louis and Auguste Lumière invented a combined camera and

projector they called the *cinématographe*, which projected moving images onto a screen.

⑯ **Airplane** Wilbur and Orville Wright built the first successful heavier-than-air, powered aircraft. Their first flight lasted only 12 seconds.

⑰ **Triode valve** First designed to control electric current, the triode valve went on to be used as an amplifier for radio and TV signals and as "switches" in computers.

⑱ **Radio broadcast** The first public radio broadcasts were heard in 1906. By the mid-1920s, people were buying radio sets for their homes.

⑲ **Television transmission** John Logie Baird produced the first television transmission using a series of spinning disks to produce the image. This mechanical device was soon overtaken by the electronic cathode ray tube.

⑳ **Transistor** The transistor did the same job as a triode valve, but it was smaller, more reliable, and used less power, paving the way for more compact electronic devices.

㉑ **Microchip** This invention integrated thousands of transistors into single miniature chips of silicon, replacing mechanical control devices in household goods and bulky circuits in computers.

㉒ **Communications satellite** The launch of the first communications satellite, Telstar, allowed live television programs and telephone calls to be transmitted around the world by bouncing signals off the orbiting space satellite to receiver dishes on the ground.

㉓ **Personal computer** The first successful desktop computer, Apple II, had an integrated keyboard, which connected to a television.

㉔ **Cell phone** Calls are transmitted via a network of short-range local transmitters using radio waves instead of cables.

㉕ **Compact disc** The CD uses a laser to read sound information recorded as a series of pits under the disc's smooth surface.

㉖ **iPhone** As technology advances, electronic devices become smaller and more intricate. Gadgets, such as Apple's iPhone, are designed to perform many different functions, including playing music and videos, storing photos, and accessing the Internet.

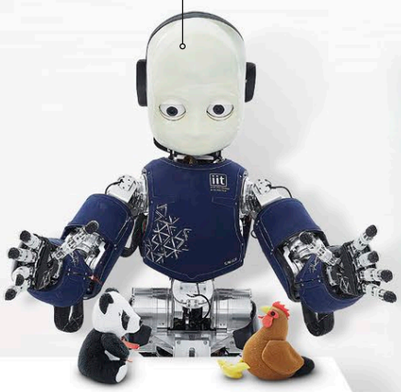
㉗ **3-D printer** Unlike ordinary printers, these printers can create three-dimensional (3-D) objects, which have width, height, and length, or depth. Regular printers use ink, but 3-D printers mostly use layers of melted plastic to create a model. Metal, chocolate, or even concrete can be used as material to create models.

ROBOTS

A robot is a machine that appears to think and act for itself. The simplest type of robot is a mechanical toy, or automaton, which has been programmed to perform a series of actions that usually have no real function. Some robots are remote-controlled devices, guided at a distance by a human operator. The most complex robots have artificial intelligence– an ability to make decisions for themselves, solve problems, and learn.

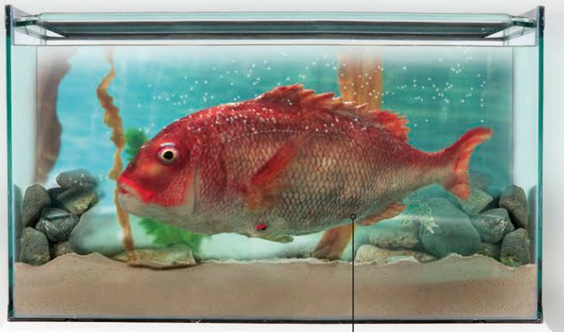
▲ SURGEON ROBOT

Surgical robots, such as da Vinci, can insert minute instruments and a viewer called an endoscope into an incision less than a half inch (1 cm) wide. The surgeon studies the operation site on a screen and moves the robot's instruments by remote control.



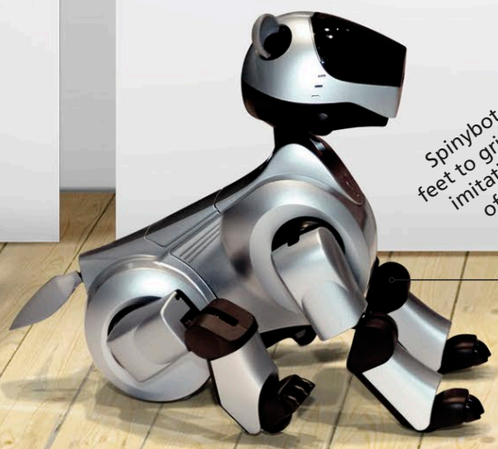
◄ HUMANOIDS

Humanoid robots, such as Jia Jia, iCub, and NAO, are created to resemble human beings. They have a head and a face, and while some walk on two legs, others may roll on tracks or wheels.



▲ ANIMAL ROBOTS

Robots that imitate the way different types of animals move and behave are vital steps in the development of ranges of movement that may be needed in robots of the future.



INDUSTRIAL ARMS ►

Most industrial robots are computer-controlled mechanical arms. They do jobs that would be difficult or dangerous for humans, or jobs that require constant repeated actions. A robot can do all these jobs more quickly or accurately than a human—and without needing to rest.

The task of welding in a car factory is carried out by robots

▲ SPACE TRAVELERS

In space, robot spacecraft and surface vehicles called rovers, such as Mars 2020, are sent to explore places that are too dangerous to send human astronauts. The movements of these robots are preprogrammed or directed from Earth, though the rovers also use camera data to avoid obstacles.

HELP AT HOME ►

Although no one yet has an android servant doing all the domestic chores, some robots are at work in homes, performing repetitive jobs, such as vacuuming floors and mowing lawns. These robots are programmed to avoid hazards in their paths.

The Roomba Intelligent FloorVac has sensors to plot its vacuuming route

▼ HELPING AT WORK

Robots are increasingly equipped to help humans carry out tasks that may be boring, repetitive, or dangerous. They work independently, guided by sensors and cameras, and can sustain themselves in bad weather, tight spaces, and rugged terrain.

MILITARY ROBOTS ►

Robot vehicles are useful in warfare because they can enter dangerous situations without risking lives. Robot devices conduct surveillance over enemy land and can find and dispose of bombs and land mines while the operator remains at a safe distance.

HOBO (Hazardous Ordnance Bomb Operator) carries equipment to defuse an explosive device or explode it safely

iRobot's CoWorker Office robot takes pictures with a camera on its rotating neck

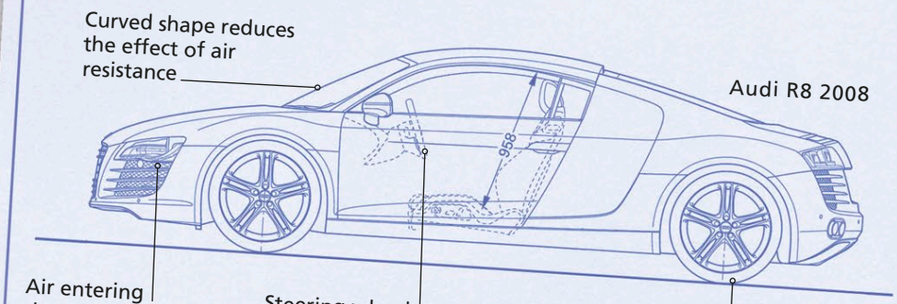
Robug III's legs allow it to cross uneven surfaces to investigate hazardous situations with an onboard camera

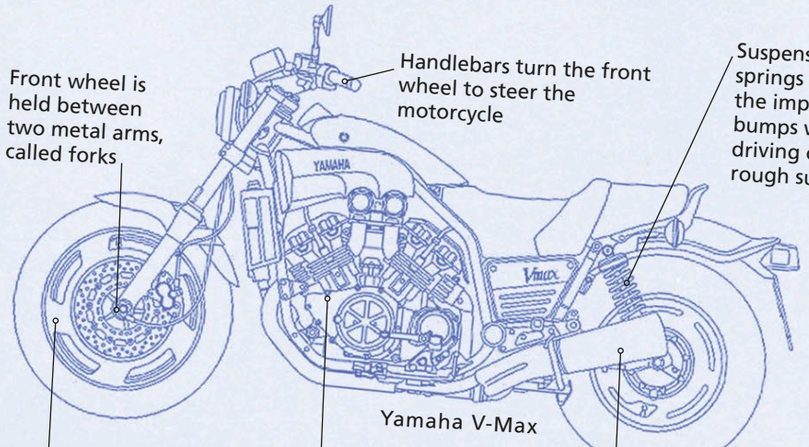
TRANSPORTATION

The world today is constantly on the move. It is impossible to imagine life without the planes, trains, ships, and cars that transport people and goods every day. Each of these incredible machines has been specifically designed to travel over land, through the air, and under or over the water.

BY ROAD ▼

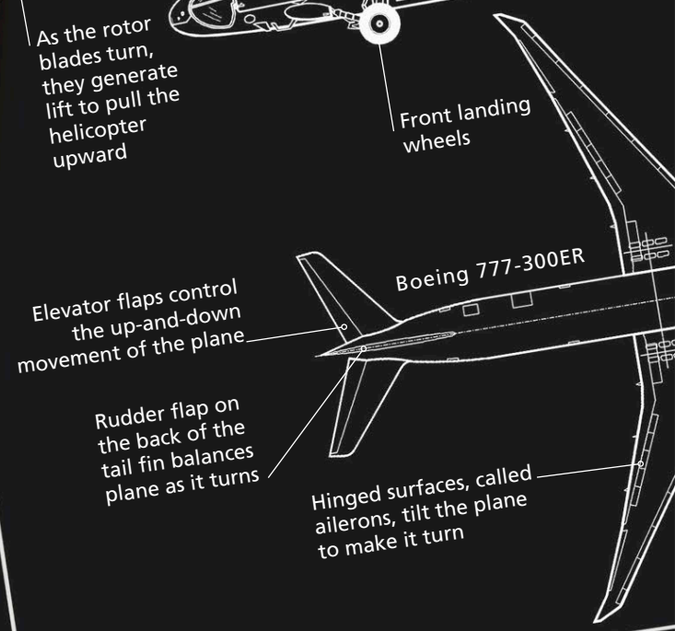
Most road vehicles have an internal-combustion engine, which burns fuel to make the power that turns the wheels. In a car, the engine is usually in the front and drives either the front or the back wheels. In a motorcycle, the engine is placed between the two wheels.

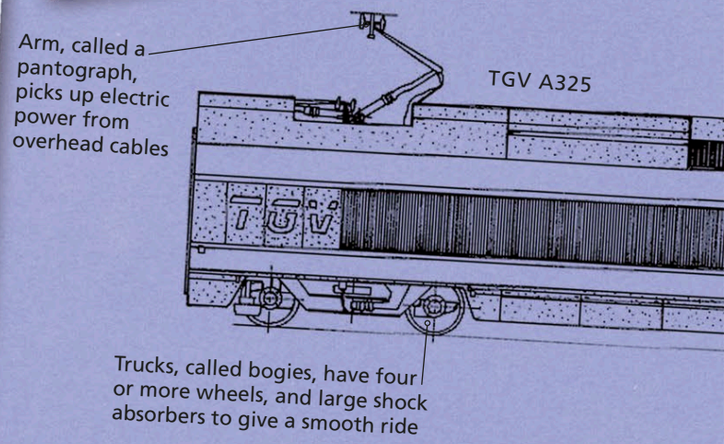


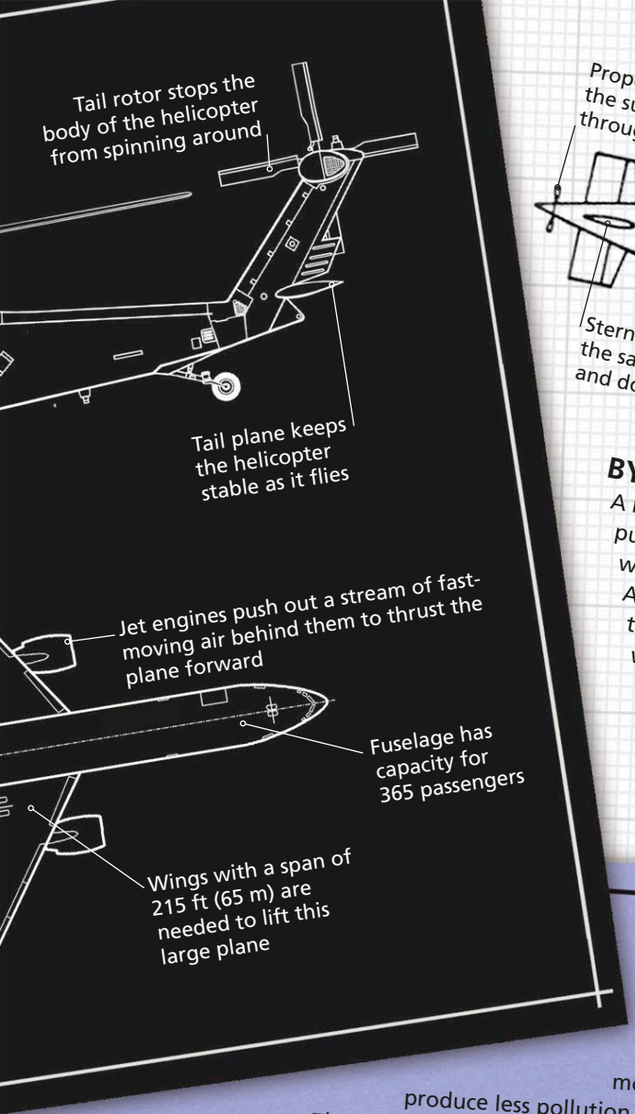


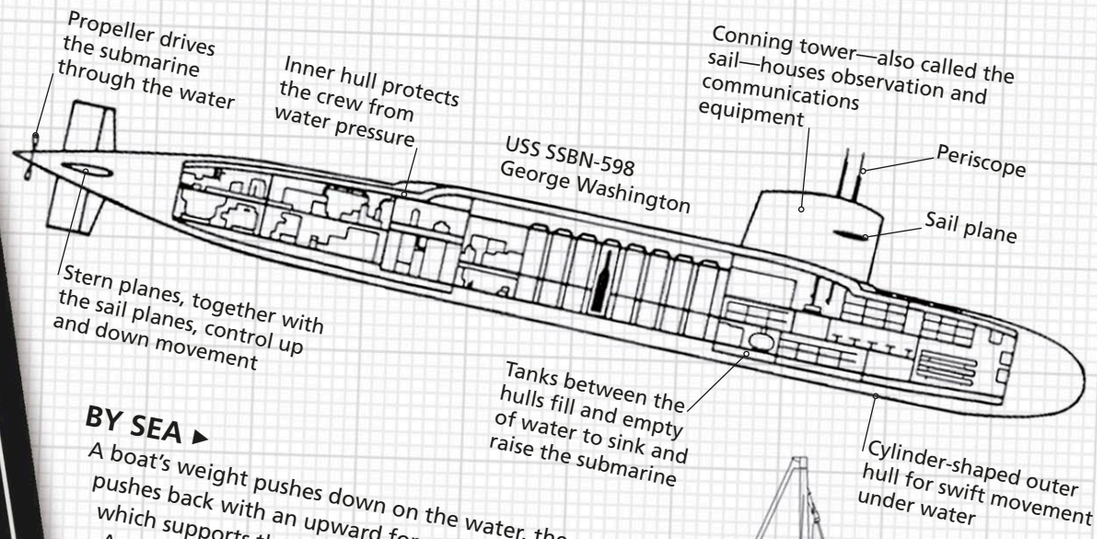
BY AIR ▼

To travel through the air, aircraft must overcome the force of gravity, which pulls them toward the ground. They achieve this with the help of curved wings and rotors, which produce an upward force called lift as they pass through the air.



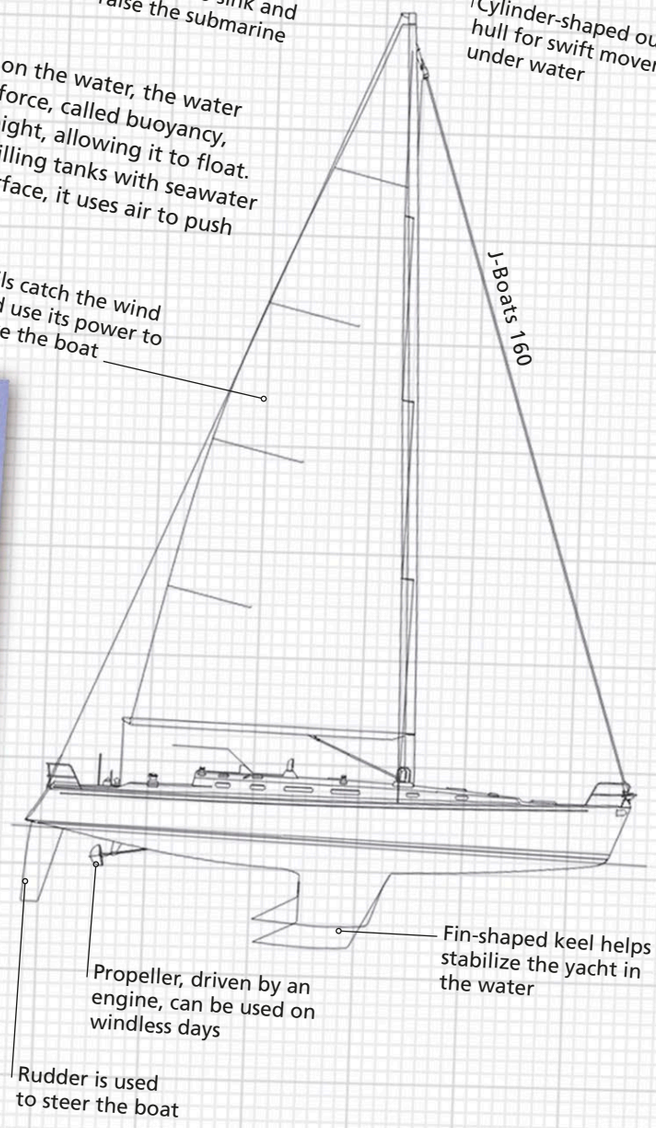






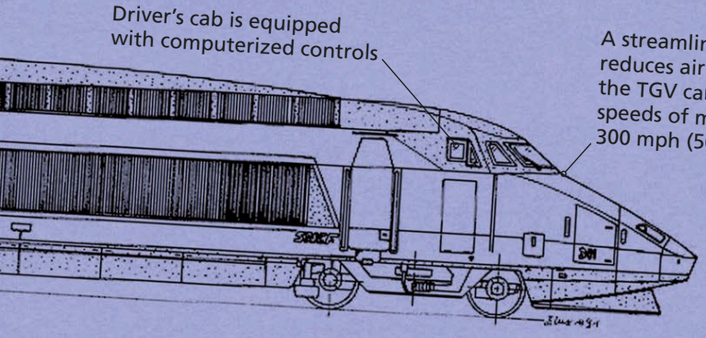
BY SEA ▶

A boat's weight pushes down on the water, the water pushes back with an upward force, called buoyancy, which supports the boat's weight, allowing it to float. A submarine submerges by filling tanks with seawater to increase its weight. To surface, it uses air to push water out of the tanks.



BY RAIL ▼

Trains carry large cargoes of people or goods and, as a result, are much more fuel-efficient and produce less pollution than cars and trucks. The fastest trains, such as France's TGV, have electric motors, but most trains are powered by diesel engines. Trains can be pulled by one locomotive (powered vehicle) at the front but can have two or even more.



SCIENTISTS

Scientists study the universe to find out how and why things happen. There are many different branches of science, such as physics, chemistry, and astronomy. Scientists make careful observations of the phenomena they are studying. They construct possible explanations for their observations, known as theories or hypotheses. Then they experiment to test whether their theories are accurate.

❶ SIR ISAAC NEWTON

English physicist and mathematician Newton (1642–1727) proposed the laws of motion that explain how forces move objects and went on to devise a theory of gravity. Newton also studied optics, the science of light, and explained how white light is made up of many colors.

❷ MARIE CURIE

Marie Curie (1867–1934) was born in Poland but carried out her investigations into radioactivity in Paris with her French husband, Pierre. She discovered the elements (substances) polonium and radium in 1898 and won two Nobel Prizes. Marie Curie died of leukemia, probably due to long exposure to radiation.

❻ BLAISE PASCAL

Frenchman Pascal (1623–1662) explored many practical applications of science and mathematics. He invented a mechanical calculator, a device made up of dials and gears, as well as a type of syringe. He also did experiments with air pressure.

❼ GALILEO

Italian astronomer and mathematician, Galileo (1564–1642) was the first person to use a telescope for studying the sky. He discovered the four largest satellites of Jupiter, today known as the Galilean moons.

❸ LUIGI GALVANI

Italian scientist Galvani (1737–1798) studied the role of electrical impulses in animal tissue by experimenting on frogs. Although his theory that the electricity was coming from the animal tissue was wrong, his discoveries led to the invention of the battery by Alessandro Volta.

❹ ALBERT EINSTEIN

Einstein (1879–1955) was born in Germany, but after Hitler came to power, he fled to the United States. Einstein revolutionized physics with his studies of relativity, which show how matter, energy, space, and time are connected. Einstein was awarded the Nobel Prize for Physics in 1921.

❺ ALEC JEFFREYS

British geneticist Jeffreys (born 1950) discovered that each individual has certain distinctive patterns of DNA and worked out how to make images of these DNA sequences. He pioneered DNA fingerprinting, used by forensic scientists in criminal investigations to identify people from traces of DNA.

❽ COPERNICUS

Polish astronomer Copernicus (1473–1543) is considered to be the founder of modern astronomy. His studies of the orbits of the planets revealed that the sun is at the center of the solar system. At the time, the predominant view was that Earth was the center of the universe.

❾ ALESSANDRO VOLTA

In 1800, research into electric currents led Italian physicist Volta (1745–1827) to invent the battery. Volta's battery, or "voltaic pile," was the first reliable means of producing an electric current and so made it easier to perform further experiments with electricity.

❿ BENJAMIN FRANKLIN

US statesman, writer, and scientist, Franklin (1706–1790) conducted research into electricity. He proved that lightning is an electrical current and suggested the use of lightning conductors to protect buildings from lightning strikes.

THE FIRST GALAXIES
This view is part of an image recorded by the Hubble Space Telescope that shows about 10,000 galaxies. It is the deepest view ever taken of the universe, looking back through time to the very first galaxies.

Space

UNIVERSE

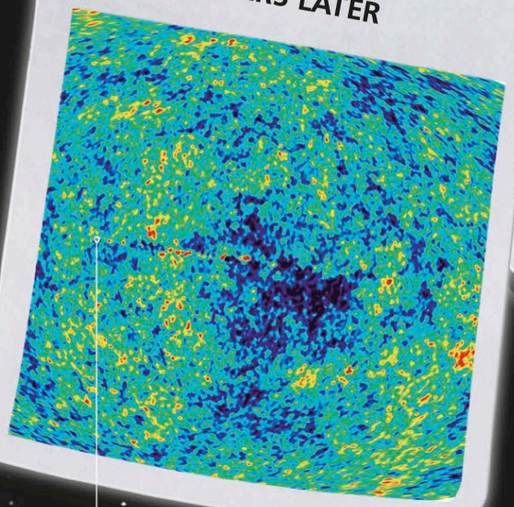
The universe is everything that exists, from the smallest particle on Earth to the vast galaxies of deep space. Every part of it, including space and time, came into existence in the Big Bang–a huge explosion that occurred about 13.8 billion years ago. At that time, the universe looked nothing like it does today, and it has been expanding, cooling, and changing ever since. The hydrogen and helium of the very young universe formed stars, which in turn produced all the other elements in today's universe, including those that make Earth and everything on it, including you.

13.8 BILLION YEARS AGO

THE BIG BANG

In the beginning, the universe was unimaginably small, dense, and incredibly hot. Within a trillionth of a second, it ballooned from being smaller than an atom to bigger than a galaxy. It was made of tiny particles of energy that turned to particles of matter. Within three minutes, the universe was almost entirely made of the nuclei of hydrogen and helium atoms.

380,000 YEARS LATER



COSMIC BACKGROUND

By looking at the heat left over from the Big Bang, known as the cosmic microwave background radiation, scientists are able to build up a picture of the early universe. This image is a heat map of the universe 380,000 years after the Big Bang. It shows that matter was not evenly distributed—the hotter areas (red) are more densely packed regions, where galaxies will form.

Colors denote minute variations in the temperature of the matter—the red areas are the hottest

12 BILLION YEARS AGO

FORMATION OF GALAXIES

Over millions of years, hydrogen and helium clumped together to form vast clouds. These broke into fragments, which collapsed under gravity and became stars. About 1 billion years after the Big Bang, a universe of dwarf galaxies had formed. These collided, merged, and changed shape to become spiral and elliptical galaxies.

The smallest, reddest galaxies date from about 800 million years after the Big Bang and are the oldest known

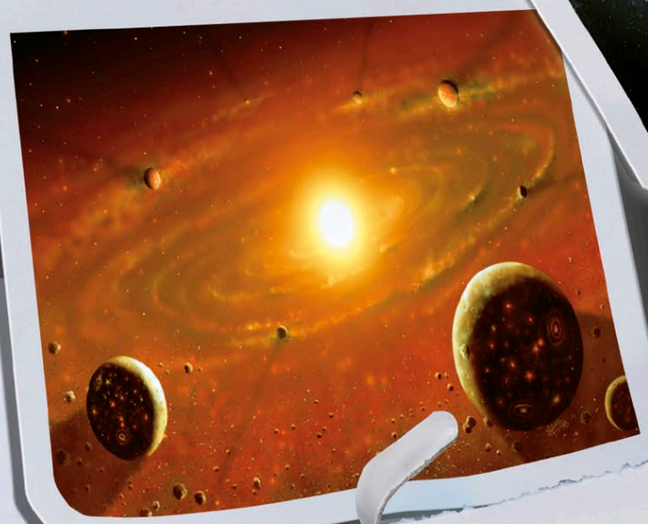
Galaxies and stars account for just 15 percent of all matter in the universe

10 BILLION YEARS AGO

BIRTH OF THE SOLAR SYSTEM

The solar system formed from a cloud of gas and dust within the disk of the Milky Way galaxy. The spinning cloud, known as the solar nebula, collapsed in on itself under the force of gravity. It first formed a central sphere—the young sun—and then the unused material surrounding the sun formed the planets, moons, asteroids, and comets.

4.6 BILLION YEARS AGO



YOUNG MILKY WAY

The Milky Way galaxy, the galaxy we live in, formed at the same time as the other galaxies. Not all of today's Milky Way stars existed at that time. Since its beginning, the galaxy has produced stars that shine brightly for millions or billions of years but that die eventually. Their remains produce a new generation of stars.

4.5 BILLION YEARS AGO

Rock from Earth's mantle is thrown out as the asteroid hits the planet

FORMATION OF THE MOON

Earth formed as ever-larger lumps of unused material collided and joined together. Young Earth was hit by a Mars-sized asteroid. Molten rock from the collision splashed into space. This formed a ring of rubble around Earth that clumped to form a large sphere—Earth's moon.

TODAY

Water—in the oceans, lakes, atmosphere, and ice caps—has been a key factor in the developement of life on Earth

HOME PLANET

Earth, the third rock planet from the sun, is the only place in the universe where life is known to exist. Life started in its oceans at least 3.7 billion years ago. Bacteria-like cells evolved into sea creatures, then land-based plants, and animals. Humans first walked on Earth about 1 million years ago.

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GALAXIES

A galaxy is a vast group of stars held together by gravity–it is thought that there could be some 2 trillion stars in our universe. They are not scattered randomly but exist in clusters, vast distances apart. All the galaxies together take up just 2 millionths of space.

1 SIZE

Galaxies are huge. The largest are more than a million light-years across (one light-year is the distance that light travels in a year). The smallest, called dwarf galaxies, are a few thousand light-years wide. Andromeda measures 220,000 light-years from side to side.

2 SHAPE

A single galaxy is made of billions or trillions of stars arranged in one of four basic shapes: spiral, barred spiral, elliptical, or irregular. Spirals and barred spirals are disk-shaped with arms of stars. In a spiral, such as Andromeda, the arms wind out from a central bulge, while in a barred spiral, they flow from the ends of a central bar of stars. Elliptical galaxies are ball-shaped. Irregular galaxies have no clear shape.

3 ORBITING STARS

Galaxies do not behave like solid objects. Each star follows its own orbit around the center of the galaxy. Stars in a spiral galaxy typically take a few hundred million years to make an orbit. Those farther away take longer than those closest to the core.

4 SPIRAL ARMS

Stars exist throughout a spiral galaxy's disk. The arms stand out because they are full of very bright young stars.

5 CORE

The core of a spiral galaxy typically consists of old red and yellow stars, with a supermassive black hole in its center. Andromeda's black hole is as massive as 30 million suns.

6 DUST LANES

Dense clouds and lanes of dust within the galaxy's disk hide stars from view.

7 DWARF GALAXY

M110 is one of the dwarf elliptical galaxies that orbit Andromeda. It is held in its orbit by Andromeda's gravity.

▲ ANDROMEDA GALAXY

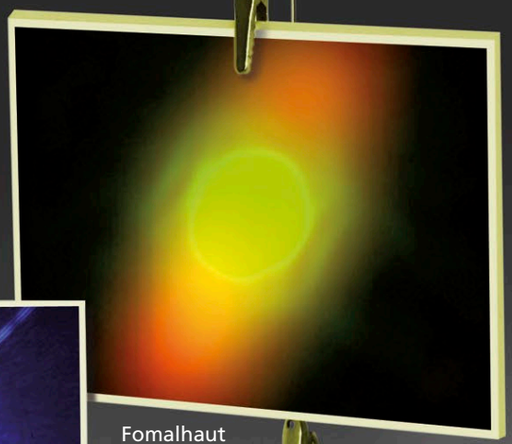
Andromeda is one of the closest galaxies to our own, the Milky Way. It is a spiral galaxy 2.5 million light-years away from us—the most distant object that can be seen by the naked eye from Earth.

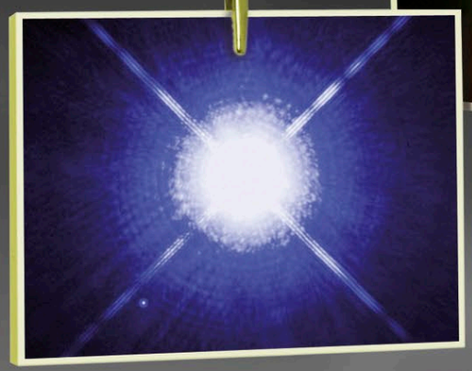
STAR BIRTH ▼
Stars are formed inside vast clouds of hydrogen gas, such as the Eagle Nebula. A small fragment of cloud collapses under gravity. It becomes increasingly squashed and eventually forms a spinning ball of gas termed a protostar—the first sign of a new star.

Eagle Nebula

Detail of the Eagle Nebula

MIDLIFE STARS ▼
Most stars glow steadily for most of their lives. During this stage they are known as main sequence stars—the sun is one. Planets orbit around some stars; others, such as Fomalhaut, have disks of dusty material that may form planets.


Fomalhaut


Sirius, the brightest star in Earth's night sky

Albireo, a double star system

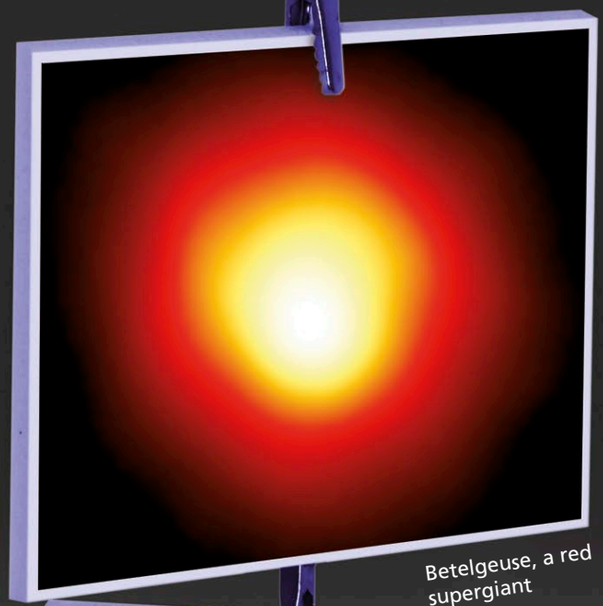
Trapezium cluster

Jewel Box cluster

◄ YOUNG STARS
A protostar gets denser and hotter as its gas becomes more squashed. When its core reaches about 18 billion°F (10 billion°C), nuclear reactions start. Hydrogen is converted to helium, energy is produced, and the star shines. Stars born at the same time and from the same region of cloud exist as a cluster. Some clusters, like the two shown here, remain together for millions of years, but eventually their stars drift apart.

STARS

Stars are huge spinning balls of hot, luminous gas. Each one is unique because stars differ in color, temperature, size, brightness, and mass. Over time, characteristics change, and the star evolves from one stage of star life to another. The key to a star's life is its mass–the amount of gas it is made from. Mass determines the star's life span as well as its other characteristics and how these change.



Betelgeuse, a red supergiant

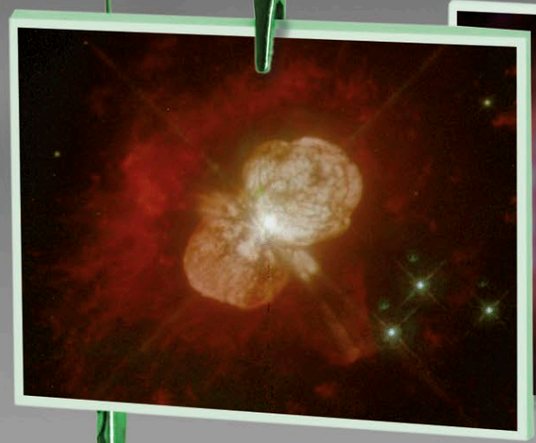
Helix Nebula

Cat's Eye Nebula, with a white dwarf visible at its center

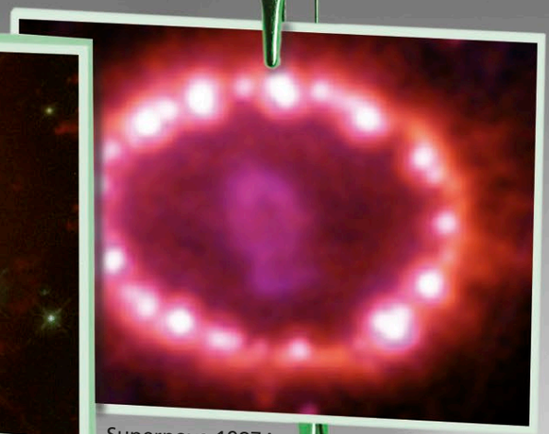
▲ DYING STARS

When a star with a mass of up to eight times that of the sun runs out of hydrogen, it swells up, cools, and becomes a red giant. Eventually, the giant star ejects its outer layers and becomes a planetary nebula. The ejected gas slowly disperses, leaving behind a white dwarf—the tiny, slowly cooling core of the original star.

Red supergiant V838 Monocerotis surrounded by a cloud of dust and gas



Ejected material from Eta Carinae, an old star expected to go supernova at any time

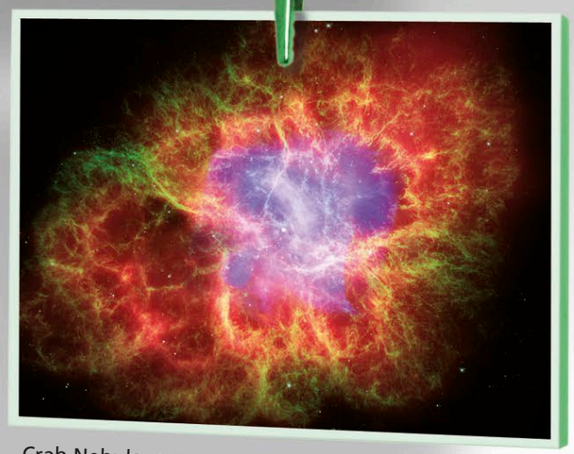


Supernova 1987A

SUDDEN DEATH ►

Aging stars with eight or more times the mass of the sun swell into enormous, unstable supergiant stars, which can end their lives in a sudden and spectacular explosion known as a supernova. The exploding star creates an extremely hot gas cloud called a supernova remnant, while its core can collapse to become a rapidly rotating, very dense pulsar or a black hole (where the core collapses in on itself under gravity until it is a hole in space). The material dispersed into space forms clouds, which in turn can give birth to new stars.

Crab Pulsar



Crab Nebula, a supernova remnant

GEMINI
TAURUS
Pleiades
Aldebaran
CANIS MINOR
Betelgeuse
ORION
MONOCEROS
Sirius
CANIS MAJOR
LEPUS
ERIDANUS
COLUMBA
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CONSTELLATIONS

Stargazers have always looked for patterns in the night sky, using imaginary lines to link stars and form the shape of a creature or object. Known as constellations, these patterns help us navigate the sky. The first of them were used about 4,000 years ago. Today, Earth's sky is divided into 88 constellations. Just over half are characters from Ancient Greek mythology, such as Orion and Taurus.

NIGHT SKY

The region of sky above is centered on the constellation of Orion. Orange lines mark a constellation's boundary, white lines link its bright stars, and the imaginary pattern is shown in light blue.

❶ GEMINI

The two brightest stars in Gemini mark the heads of the mythological twins Castor (right) and Pollux (left). Castor's head is in fact six stars, and Pollux's is an orange-colored giant star.

❷ TAURUS

The head of Taurus the bull is drawn around the Hyades, a V-shaped star cluster. Aldebaran, a red giant star, is the brightest of his eyes. The Pleiades star cluster marks his back.

❸ CANIS MINOR AND MAJOR

Orion's dogs are known as Canis Major and Canis Minor. Canis Major, the larger dog, contains Sirius, sometimes called the Dog Star, the brightest star in the night sky.

❹ MONOCEROS

The unicorn Monoceros was introduced in 1613. It lies in the path of the Milky Way—the glowing band of stars that stretches across the sky (here from bottom left to top center).

❺ ORION

The hunter Orion is visible from nearly everywhere on Earth. His raised arms hold a club and a lion's head. The red star in one of his shoulders is the red supergiant Betelgeuse.

❻ ERIDANUS

This constellation is the sixth largest in the sky and represents the river into which Phaethon, the son of the Greek Sun god Helios, plunged when he lost control of his father's golden chariot.

❼ PUPPIS

According to Greek myth, Puppis is the stern of the ship sailed by legendary hero Jason. Other parts of the ship are represented by the constellations Carina (the keel) and Vela (the sails).

❽ LEPUS

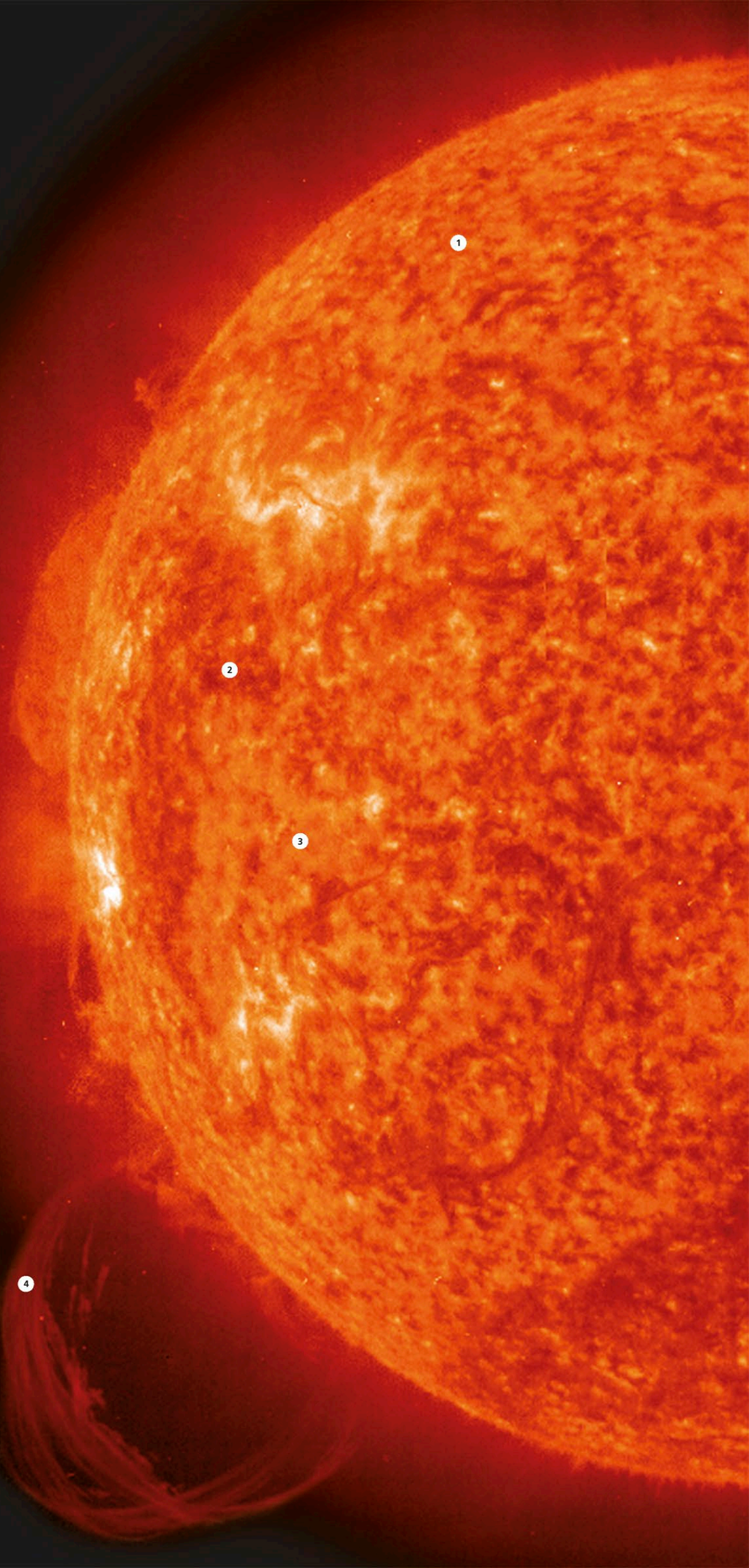
Orion's larger dog chases Lepus the hare across the sky. It is one of more than 40 creatures in the night sky. There are also 13 human figures and two centaurs (half man, half horse).

❾ COLUMBA

It is thought that Columba, the dove, is the bird that was sent from Noah's ark to find dry land, as told in the Bible. It may also represent a dove sent out to guide Jason in Ancient Greek myth.

SUN

The sun is the closest star to Earth and the center of our solar system. This vast ball consists of hot luminous gas kept together by gravity. About three-quarters is hydrogen, and almost all the rest is helium, with small amounts of about 90 other elements. More than half of the gas is squashed in the sun's core where nuclear reactions convert hydrogen to helium and in the process produce huge amounts of energy. This energy is released through the sun's surface, most familiarly as heat and light. The sun has been producing energy in this way for about 4.6 billion years and will do so for another 5 billion or so. This image shows the sun not as it appears to the human eye, but in ultraviolet light.



❶ SIZE

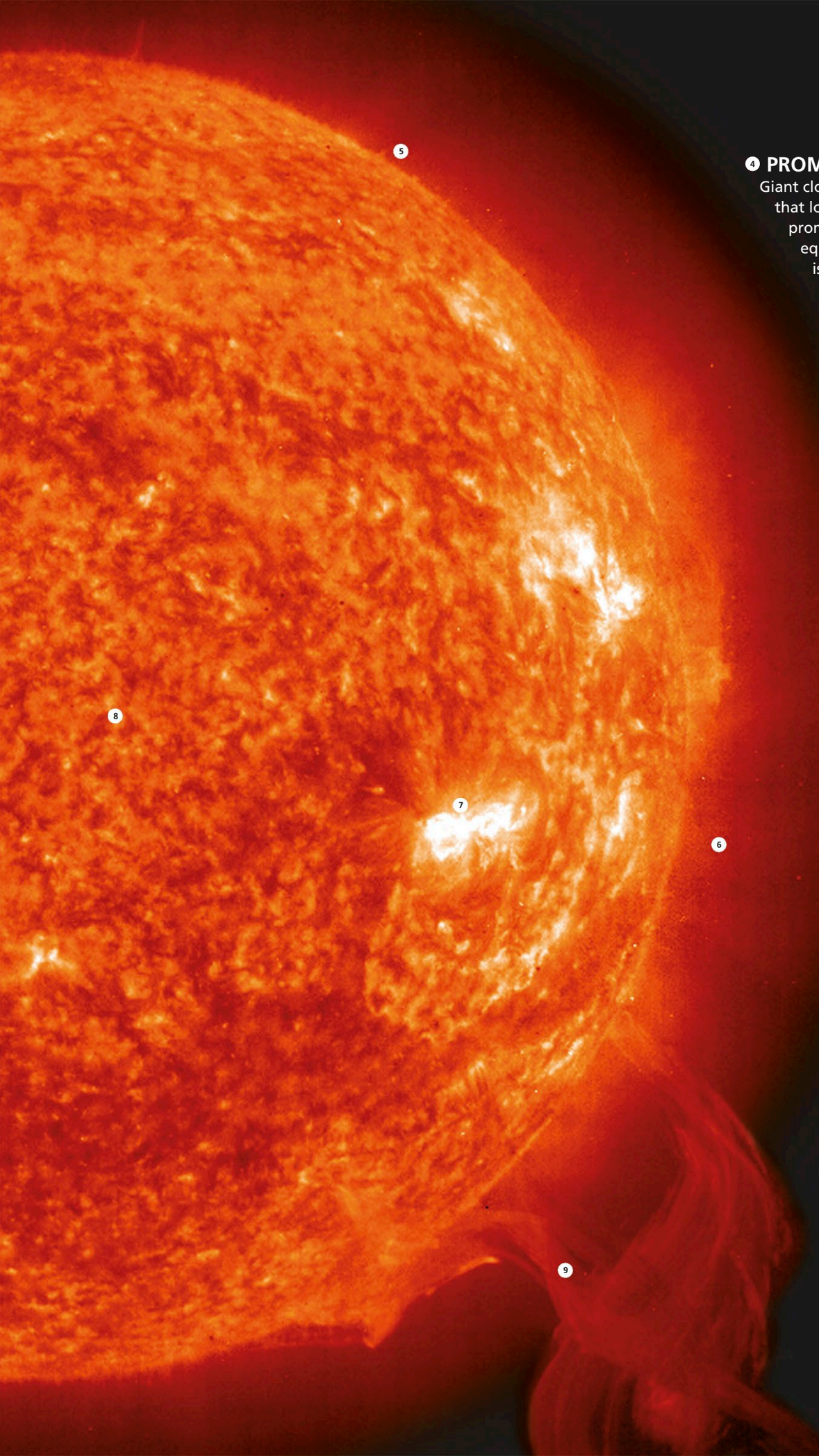
The sun is the largest body in the solar system. It measures 870,000 miles (1.4 million km) in diameter, which means that 109 Earths could fit across its face. The sun is made of 330,000 times more material than Earth, and 1.3 million Earths would fit inside it.

❷ PHOTOSPHERE

Like other stars, the sun is not solid but has a visible surface called the photosphere—a violent place where jets and flares of gas constantly shoot into space. It is made of 600-mile (1,000 km) wide short-lived granules of rising gas, which together resemble orange peel.

❸ TEMPERATURE

The temperature of the surface is 9,900°F (5,500°C), and it is this that gives the sun its yellow color. Cooler stars are red; hotter ones are white. Inside is much hotter. The core is 27 million°F (15 million°C), and nuclear reactions here convert 600 million tons of hydrogen to helium every second.



❹ PROMINENCE

Giant clouds and sheets of relatively cool gas that loop and arch from the surface are called prominences. This one extends out the equivalent of about 20 Earths. The gas is propelled from the surface by enormous force built up by magnetic fields inside the sun.

❺ SPICULES

Short-lived flamelike jets of gas called spicules continuously leap about 6,000 miles (10,000 km) from the surface.

❻ ATMOSPHERE

Directly above the surface is the chromosphere, the inner atmosphere that extends out about 1,550 miles (2,500 km). Beyond is the corona, which extends for millions of miles into space. Only the inner corona is visible here.

❼ FACULAE

The hottest areas, which appear almost white, are faculae. They are particularly active regions produced by concentrations in the sun's magnetic field.

❽ SPIN

Unlike Earth, which is solid and spins as a whole, different parts of the sun spin in different amounts of time. The equator makes one rotation every 25 days; regions near the poles take another five or so days.

❾ CORONAL MASS EJECTION

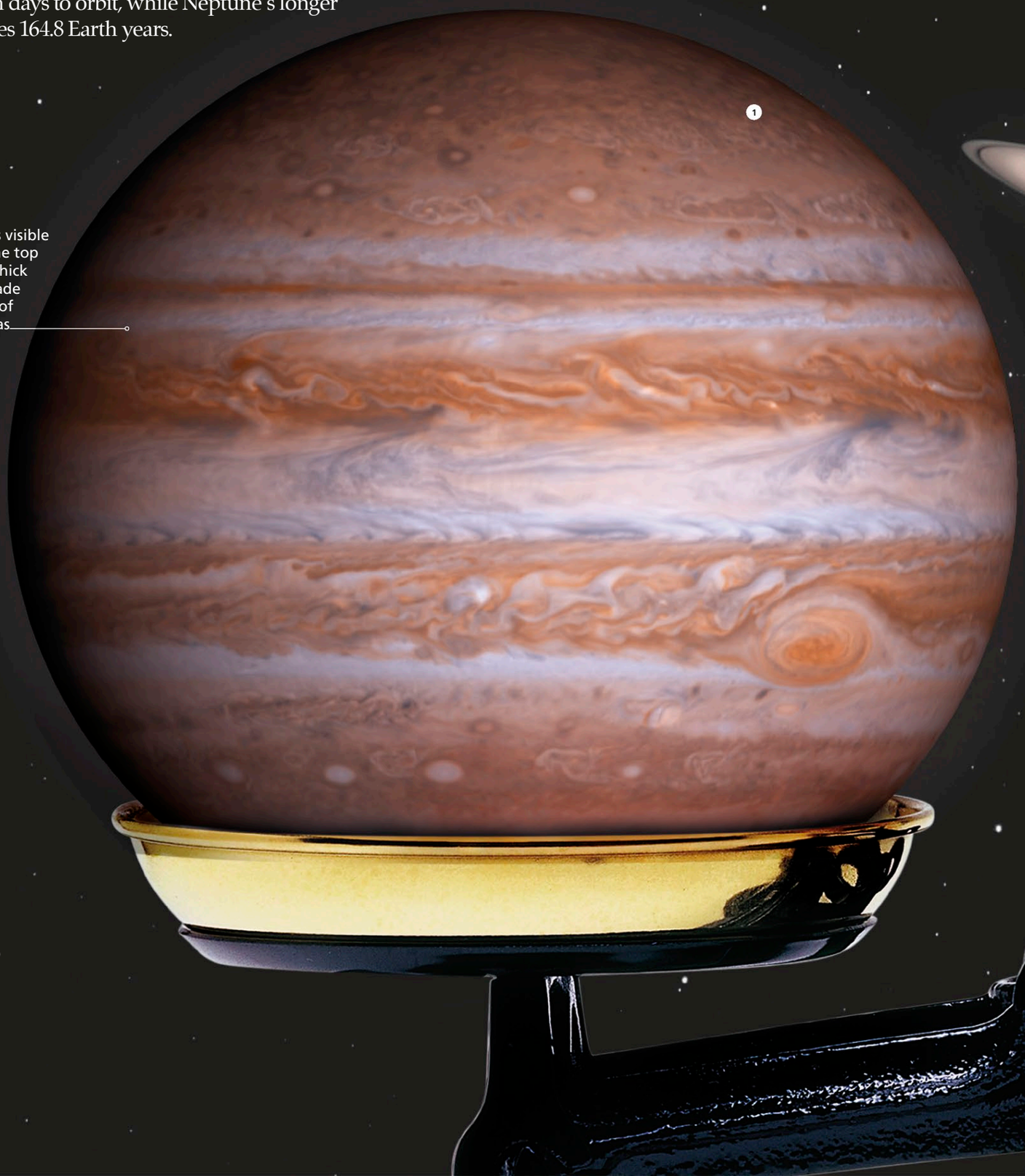
This twisting prominence was associated with a coronal mass ejection—a large bubble of billions of tons of gas that blasted away from the sun.

PLANETS

Hurtling around the sun are eight planets. Those closest to the sun–Mercury, Venus, our home planet Earth, and Mars–are made of rock. The vast outer planets–Jupiter, Saturn, Uranus, and Neptune–are called "gas planets" because all we see of them is their gas. All eight travel in the same direction around the sun. The time taken to make one circuit, or orbit, increases with distance. Mercury takes just 88 Earth days to orbit, while Neptune's longer journey takes 164.8 Earth years.

1 JUPITER

The largest and most massive planet, Jupiter is also the fastest spinner, rotating once on its own axis in less than 10 hours. This giant world is made mainly of hydrogen and helium, with a central rocky core. A thin faint ring encircles Jupiter, which also has a large family of moons.



Jupiter's visible surface is the top of a deep and thick atmosphere made from bands of swirling gas

❷ SATURN
Sixth from the sun, and second largest, is pale yellow Saturn. Its distinctive feature is its ring system, which is made of billions of pieces of dirty water ice. Saturn is mainly hydrogen and helium with a rocky core. It has a large family of moons.

❸ URANUS
Nineteen times the distance of Earth from the sun, Uranus is a cold, turquoise world bounded by a layer of haze. A sparse ring system encircles the planet's equator. Uranus is tilted on its side so that its rings and moons seem to orbit it from top to bottom.

❹ MERCURY
Mercury is a dry ball of rock, covered by millions of impact craters. It is the smallest planet, the closest to the sun, and has the widest temperature range of any planet. During the day, it is baking hot, but at night, it is freezing cold.

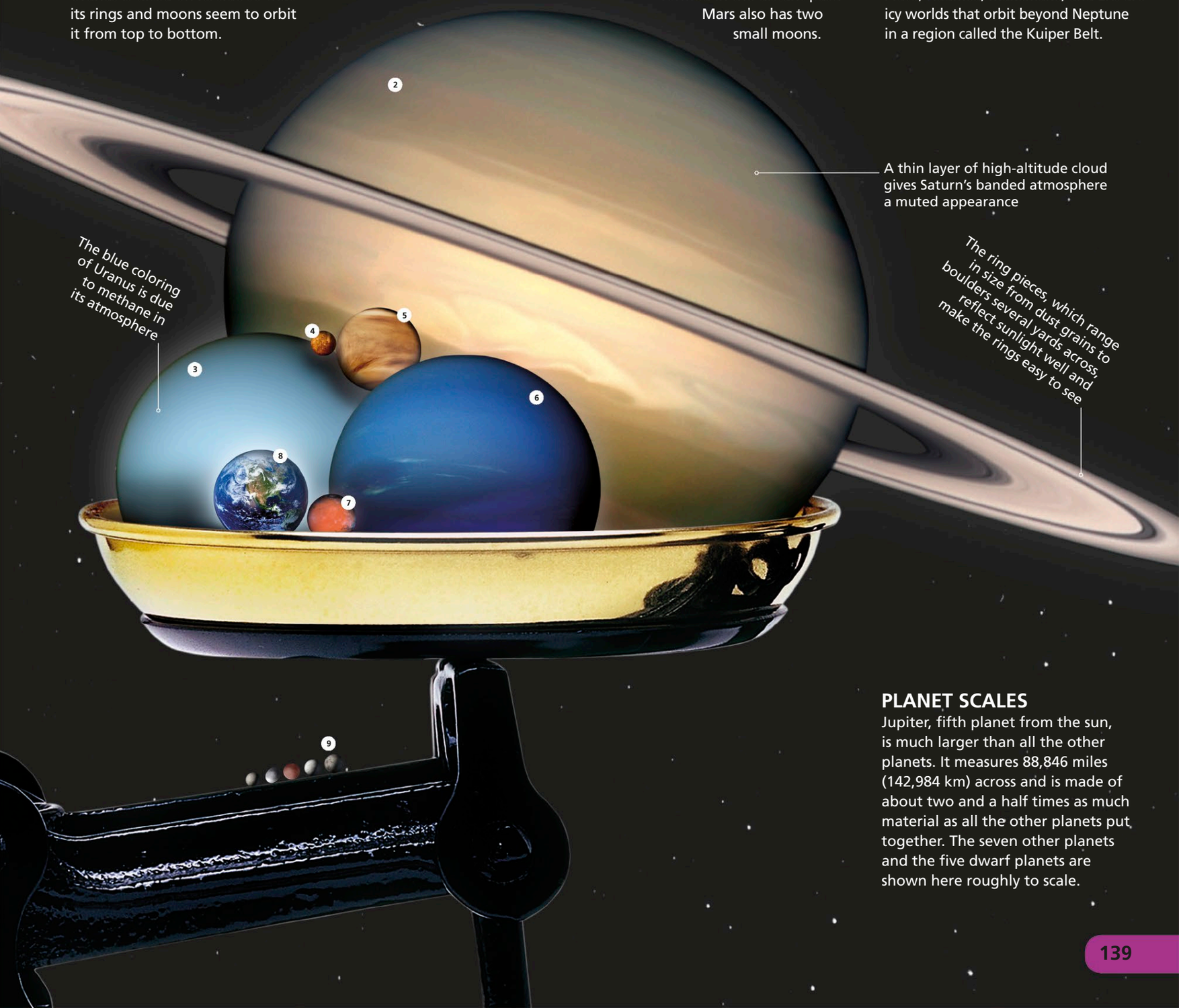
❺ VENUS
Second from the sun, Venus is the hottest planet. This rock world is permanently covered by thick cloud that traps heat and makes it a gloomy planet.

❻ NEPTUNE
Neptune is the most distant, coldest, and windiest of all eight planets. Like Uranus, it is made mainly of water, methane, and ammonia ices with an atmosphere of hydrogen-rich gas. It is encircled by a thin ring system and has a family of moons.

❼ MARS
Sometimes called the "red planet," Mars is the outermost of the rocky planets and a cold, dry world. It has polar ice caps, giant volcanoes, frozen desert, and deep canyons, formed in the distant past. Mars also has two small moons.

❽ EARTH
The only place known to have life is Earth, the largest of the rocky planets and third from the sun. It is also the only planet with liquid water. Movements in Earth's crust are constantly changing its surface. Earth has one moon.

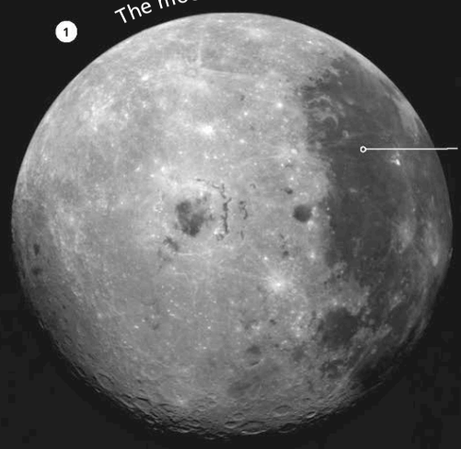
❾ DWARF PLANETS
The solar system has five known dwarf planets—small, roundish objects that orbit the sun among other objects. Ceres orbits between Mars and Jupiter within a belt of rocky asteroids, while Pluto, Haumea, Makemake, and Eris are icy worlds that orbit beyond Neptune in a region called the Kuiper Belt.

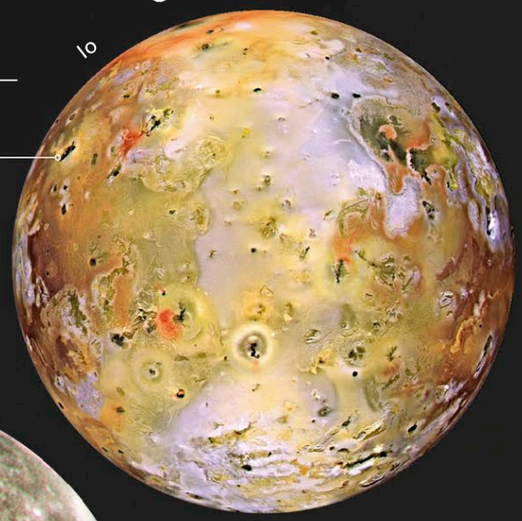


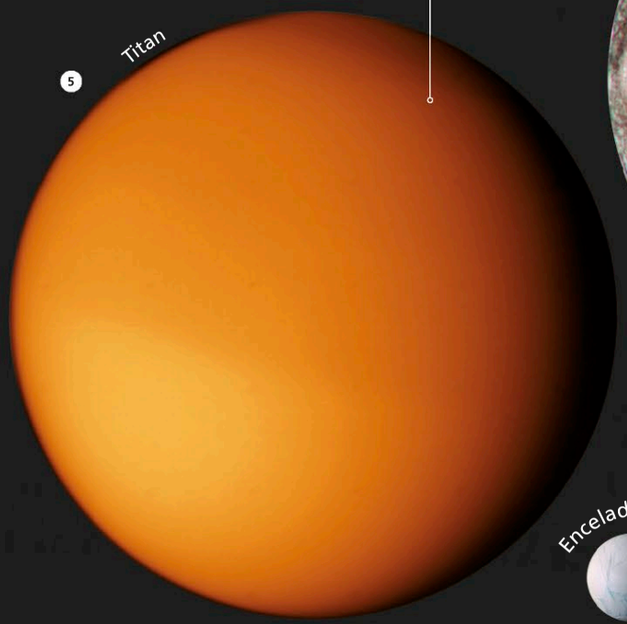
PLANET SCALES
Jupiter, fifth planet from the sun, is much larger than all the other planets. It measures 88,846 miles (142,984 km) across and is made of about two and a half times as much material as all the other planets put together. The seven other planets and the five dwarf planets are shown here roughly to scale.

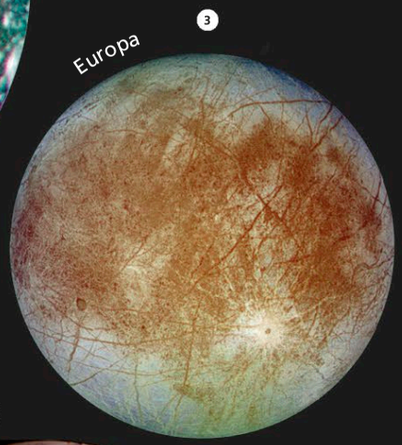
MOONS

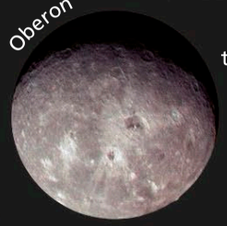
The solar system has more than 190 moons orbiting six of the planets–only Mercury and Venus are moonless. They range in size from Ganymede, a satellite of Jupiter, which is larger than Mercury, to S/2009 S1, a 980 ft (300 m) moonlet orbiting within Saturn's rings. All are made of rock, or rock and ice, and many have surfaces littered with impact craters, formed when the moons were bombarded by asteroids in the past. Nineteen solar-system moons are more than 250 miles (400 km) wide. These large moons are round, but the more numerous smaller moons are irregular in shape.

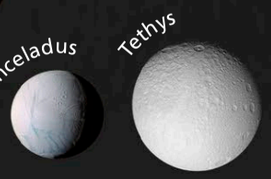


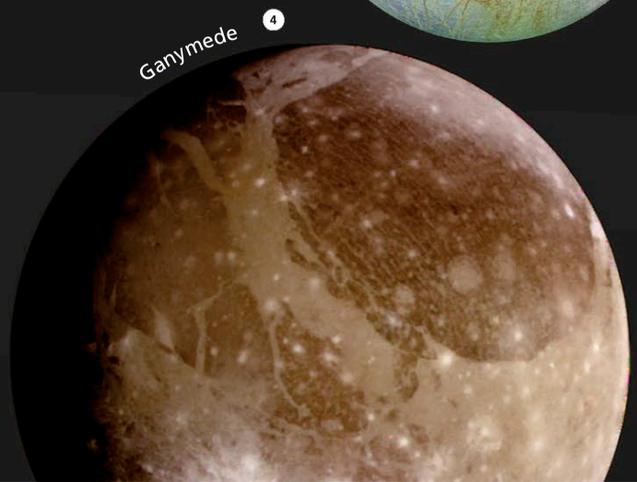


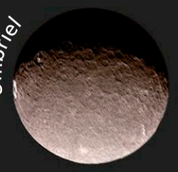


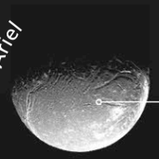


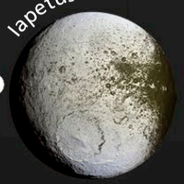










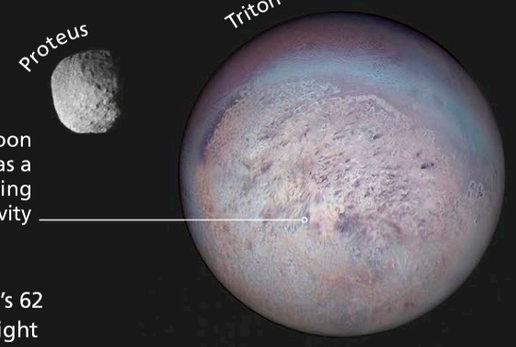


❶ THE MOON
The moon is Earth's only natural satellite. It is about a quarter the size of Earth and the fifth largest of all moons. The surface of this dry ball of rock is covered in impact craters.

❷ IO
Colorful Io is the most volcanic moon in the solar system. Its surface is constantly being renewed as molten rock erupts through its thin silicate-rock crust, and fast-moving columns of cold gas and frost grains shoot up from surface cracks.

❸ EUROPA
The smallest of Jupiter's four major moons, Europa has an icy surface crisscrossed with networks of brownish grooves. The crust slowly drifts around on top of a deep ocean of liquid water that might be home to alien life.

❹ GANYMEDE
At 3,267 miles (5,262 km) across, Ganymede is the largest moon in the solar system and belongs to the largest family of moons—the moons of Jupiter. Astronomers know of 79, but the number is likely to rise as smaller moons are detected. Ganymede is made of rock and ice with an icy crust.



Neptune's only large moon probably began life as a dwarf planet before being captured by Neptune's gravity

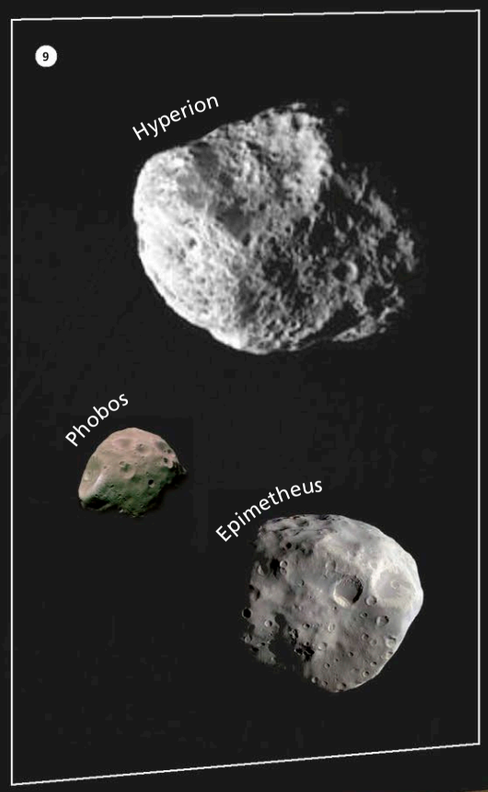
❺ TITAN
Titan is the largest of Saturn's 62 moons. On its surface are bright highlands, dark plains, and methane lakes and seas. It is the only moon with a substantial atmosphere, which is rich in nitrogen and extends out for hundreds of miles.

❻ TITANIA
Titania is the largest of the 27 moons orbiting Uranus. Titania and the planet's other major moons, Oberon, Umbriel, Ariel, and Miranda, are named after characters in English literature. Impact craters and large cracks are seen on its gray, icy surface.

❼ IAPETUS
Iapetus is a moon of contrasts. Most of its crater-covered terrain is bright and icy, but the rest appears to be coated by a dark material. It is one of Saturn's seven major moons, along with Titan, Rhea, Dione, Tethys, Enceladus, and Mimas.

❽ TRITON
Triton is by far the largest of Neptune's 14 moons, a rock-and-ice ball with a young, icy surface. It is nicknamed the cantaloupe because its linear grooves, ridges, and depressions resemble a melon's skin.

❾ SMALL MOONS
Most moons are less than 250 miles (400 km) across and irregular in shape, like Saturn's Epimetheus and Hyperion. Many of these smaller moons, like Mars's two moons Phobos and Deimos, may have started off as asteroids or comets.



COMETS

More than a trillion comets surround the planetary region of the solar system. They follow long orbits around the sun and together make up a vast sphere called the Oort Cloud. Each comet is a lump of dirt and snow, called a nucleus, or "dirty snowball." Comets are so small that they are visible only when they travel close to the sun and grow large and bright enough to be seen.

CHANGING COMET ▸

As a comet approaches the sun, it warms up. The snow turns to gas, which, along with loose dust, flows from the nucleus. When the comet passes closer to the sun than the orbit of Mars, this material forms a head (called a coma) and two tails, one of gas and one of dust.

Coma A coma has formed around the nucleus of Comet Hale-Bopp as it travels toward the sun.

Tails The comet's tails increase in length as it nears the sun. They are pushed away from the sun and always point away from it.

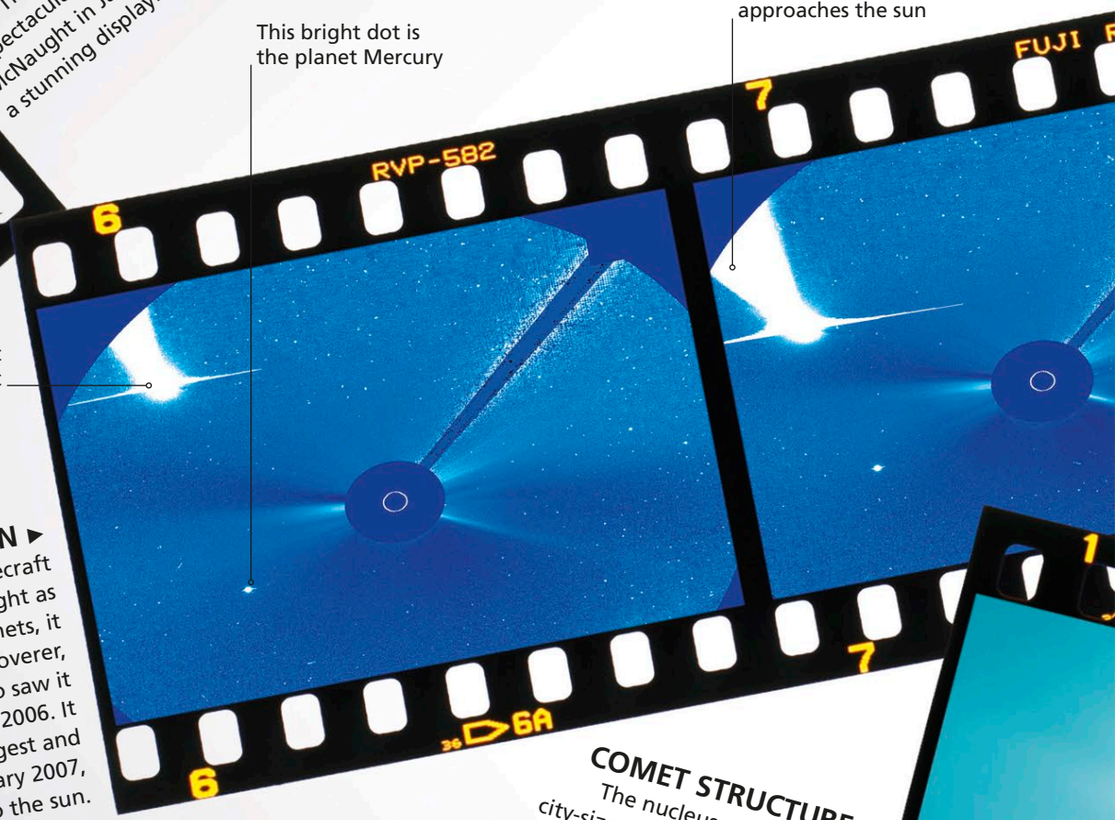
◂ COMET DISPLAY

More than 2,300 comets have been identified as they passed through the sun's neighborhood. About 200 make return visits, but most pass by just once. Three or four times a century, a spectacular one, such as Comet McNaught in January 2007, makes a stunning display.

Comet McNaught

This bright dot is the planet Mercury

The comet grows as it approaches the sun

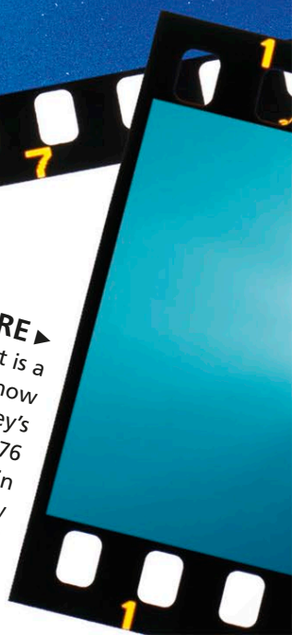


PASSING THE SUN ▸

These images from the SOHO spacecraft track the progress of Comet McNaught as it rounds the sun. Like most comets, it is named after its discoverer, Robert McNaught, who saw it first on August 7, 2006. It was at its biggest and brightest in January 2007, when closest to the sun.

COMET STRUCTURE ▸

The nucleus of a comet is a city-sized lump, two-thirds snow and one-third rock dust. Halley's Comet orbits the sun every 76 years. When it drew close to it in 1986, the *Giotto* spacecraft flew into the comet's coma and captured images of its nucleus.



Tail shapes The gas tail is blue and straight, and the dust tail is white and curved.

Closest to the sun The tails are longest when closest to the sun then shrink as the comet moves away.

Sun's bright disk has to be masked so that the comet can be imaged

Several dozen mini-fragments trail behind the main one

One of more than 30 separate fragments of Comet Schwassmann Wachmann 3

Jets of dust and gas stream out of the nucleus

The nucleus of Halley's Comet is 9.5 miles (15.3 km) long

BREAKING UP ▶

As a comet passes a massive body, such as the sun or Jupiter, it may be pulled apart by its gravity. Comet Schwassmann Wachmann 3 orbits the sun every 5.4 years, and astronomers have observed that it is disintegrating.

METEORITES

Thousands of tons of rocky material enter Earth's atmosphere each year. Most of it originates from asteroids, but some comes from comets, the moon, and even Mars. As the rocky pieces close in on Earth, they are termed meteoroids. Most burn up, but those that survive and land are known as meteorites. There are three main types: stony meteorites, iron meteorites, and stony-iron meteorites–the rarest kind.

▼ ESQUEL
This stony-iron meteorite was collected in Esquel, Argentina, in 1951. Golden-colored crystals of the mineral olivine are embedded in the iron-nickel metal.

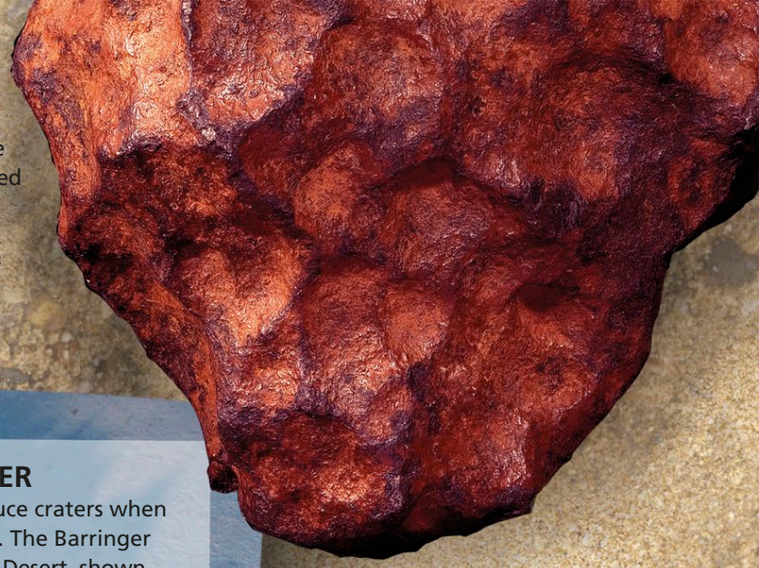
THIEL ▶
The Thiel Mountains stony-iron meteorite was one of the first found in Antarctica, in 1962.

▲ METEOR
Meteoroids burning up in Earth's atmosphere produce bright trails. These short-lived streaks of light are termed meteors, or shooting stars. About a million occur every day.

◀ MURCHISON
Stony meteorites are the most common. This one, the Murchison, fell in Australia in 1969. It is one of the most studied meteorites and contains minerals, water, and complex organic molecules.

BARWELL ▶
The Barwell meteorite is one of a shower of stones that fell in England in 1965. As it plummeted through Earth's atmosphere, friction caused the outer surface to heat and melt. This later solidified into a black crust.

◄ CANON DIABLO
This sliced and polished iron meteorite is a piece of the asteroid that produced the Barringer Crater (below). The pieces found weigh 30 tons in total, yet they are only a small fraction of the original asteroid.



▲ GIBEON
Iron meteorites are the second most common type, after stony meteorites. The Gibeon is mainly iron with a small amount of nickel. It is one of many found in Namibia since the 1830s.

▼ IMPACT CRATER
Meteorites can produce craters when they crash into Earth. The Barringer Crater in the Arizona Desert, shown here under a rare blanket of snow, measures 0.75 miles (1.2 km) across and was formed about 50,000 years ago.

▲ CALCALONG CREEK
More than 50 meteorites found on Earth originated on the moon, blasted off by asteroid impact. The Calcalong Creek meteorite, found in Australia, is lunar surface soil that was turned to rock by such an impact.

▲ NAKHLA
This stony meteorite is one of more than 30 found on Earth that originated on Mars. It was blasted off the planet and spent many millions of years in space before landing in Egypt on June 28, 1911.

◄ TEKTITES
Small glassy bodies known as tektites can form when a large meteorite hits Earth. The impact shatters and melts surrounding Earth rock, flinging it upward. It cools and hardens, falling back to Earth as glassy pieces.

THROUGH BINOCULARS ▲
The Orion Nebula is a massive star-forming cloud of gas and dust. The nebula becomes more obvious when looked at through binoculars—two low-powered telescopes working together. In standard binoculars, the two main lenses are about 2 in (5 cm) wide, and the image is magnified seven times.

IMPROVED VIEW ►
A more powerful telescope improves the view of the nebula. Across the world, there are about 50 telescopes with mirrors 7–17 ft (2–5 m) across and another 20 with mirrors up to 33 ft (10 m) across. These large telescopes are located on mountaintop sites where the air is clear and still. Computerized controls adjust their position, keeping them tracked on their target as Earth turns.

NAKED-EYE VIEW ▲
The constellation of Orion is easily visible to the naked eye. On a dark, moonless night, a faint, fuzzy patch of light may be visible below the three stars of Orion's belt. This is the Orion Nebula.

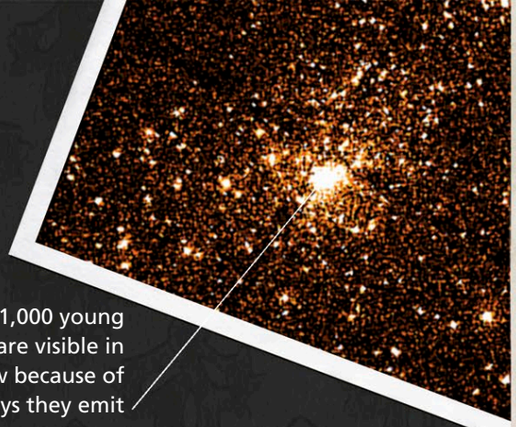
TELESCOPES

A telescope is the astronomer's basic tool. It makes distant objects appear bigger and reveals their detail. Telescopes work by using a lens or mirror to collect light and bring it to a focus, producing an image. Reflectors, which use a mirror, are the most widely used type of telescope–the bigger the mirror, the more powerful the telescope and the better the view.

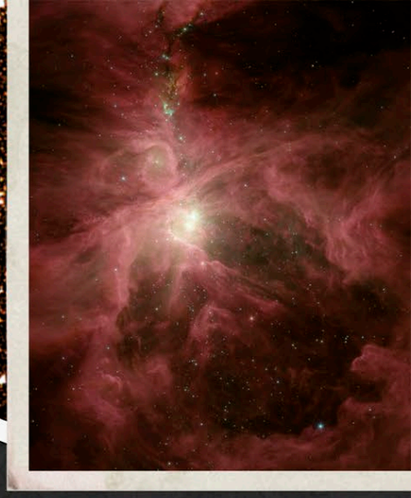
Refracting telescope uses a lens, contained within the body of the telescope, to collect and focus light

Magnifying eyepiece is at 90° to the main tube for ease of use

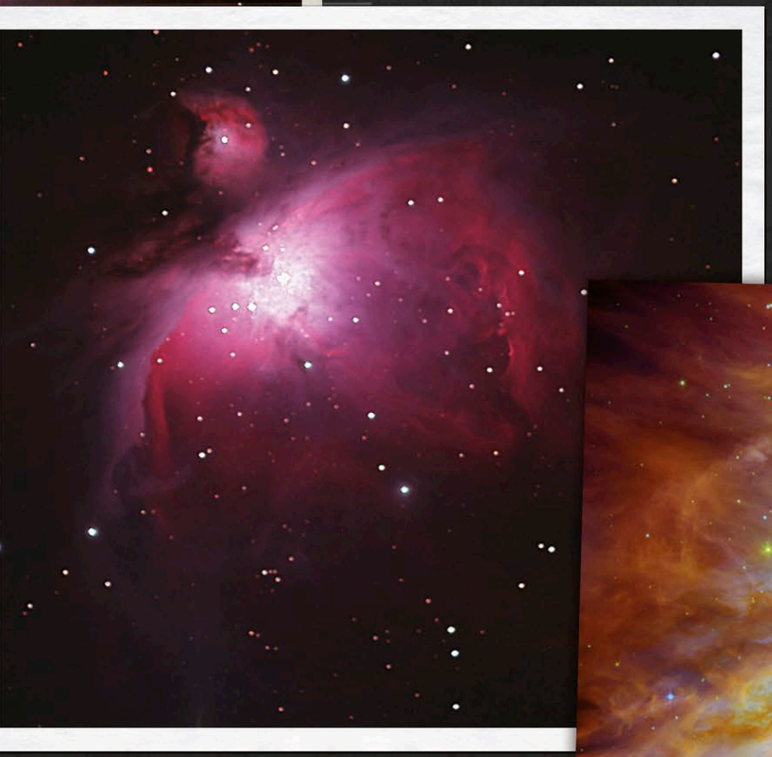
◂ MEDIUM-SIZED TELESCOPE VIEW
The nebula's shape and form become visible through a telescope with a mirror about 8 in (20 cm) across. A camera attached to the telescope collects the light and records the image.



About 1,000 young stars are visible in this view because of the X-rays they emit



X-RAY AND INFRARED VIEWS ▲
X-rays collected by the Chandra space telescope were used to make this image on the left, which shows the heart of the Orion Nebula. The image on the right shows the same area taken by the Spitzer infrared telescope. Clouds of dust heated by starlight show up in red.

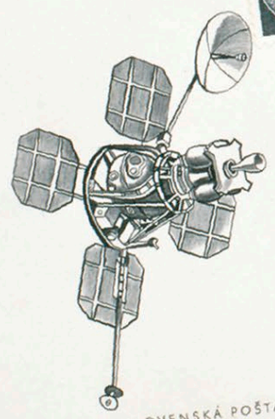


VIEW FROM SPACE ▸
Some telescopes collect forms of energy other than light, such as radio waves, X-rays, and infrared energy. Earth's atmosphere prevents some of these from reaching Earth so they are collected by telescopes in space. This color-enhanced image combines data from two space telescopes—Spitzer, which collects infrared waves, and Hubble, which collects both light and ultraviolet waves.

HEART OF THE NEBULA ▸
Hubble's 8 ft (2.4 m) wide mirror collected the light for this detailed view of the Orion Nebula's bright central area. It includes the Trapezium, a cluster of 10 young, brilliant stars that illuminate the nebula with their ultraviolet energy.

SPACE EXPLORATION

Humans have been able to send spacecraft to explore space for only about 50 years. In that time, more than 100 robotic craft have traveled into the solar system to reveal what its planets, moons, asteroids, and comets are like. They fly by, orbit, or land on these other worlds. Humans have been only to the moon but aim to set foot on Mars in the future.



Russian satellite *Sputnik 1*

Dog inside capsule

Sputnik 2 takes Laika the dog into space

Mercury Atlas 5, with chimpanzee Enos on board

Yuri Gagarin, first human in space

Valentina Tereshkova, first woman in space

Alexei Leonov makes the first spacewalk

Apollo 8 orbits the moon

Apollo 11 lifts off

In orbit over the moon

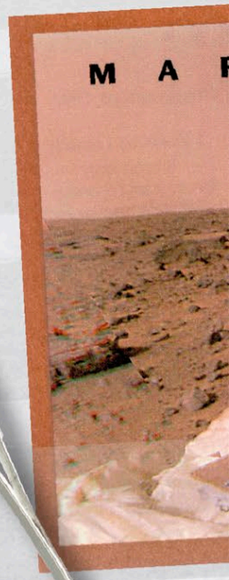
Man walks on the moon

Apollo 11 crew return to Earth in command module *Columbia*

Reentering Earth's atmosphere

Spacecraft explore the major bodies of the solar system

Apollo 18 with three US astronauts



Lunar Roving Vehicle had a maximum speed of 11.5 mph (18.6 km/h)

Apollo 15 mission

Pioneer 10 flies by Jupiter in 1973, followed by its twin, *Pioneer 11*, in 1974

Pioneer craft investigate Jupiter

Soyuz 19 with two Russian cosmonauts

First international space rendezvous

Viking craft land on Mars

Giotto craft flies into Halley's Comet

Hubble Space Telescope launched

Columbia, the first space shuttle, takes off

Mars Pathfinder and its rover, *Sojourner*, touch down on Mars

TIMELINE OF SPACE EXPLORATION

October 14, 1957
Sputnik 1, the world's first artificial satellite, is launched into Earth's orbit by Russia.

November 3, 1957
Laika, a Russian dog aboard *Sputnik 2*, becomes the first creature to orbit Earth.

January 2, 1959
Russian spacecraft *Luna 1* is the first to escape Earth's gravity.

September 13, 1959
Luna 2 is the first craft to land on the moon when it crashes onto its surface.

April 12, 1961
Russian Yuri Gagarin is the first person into space. His flight lasts 108 minutes.

June 16, 1963
Russian Valentina Tereshkova is the first woman in space.

March 18, 1965
Russian Alexei Leonov makes the first EVA (extravehicular activity), or spacewalk.

February 3, 1966
Luna 9 lands successfully on the moon.

December 24, 1968
US spacecraft *Apollo 8* is the first manned mission to leave Earth's gravity and orbit the moon.

July 20, 1969
Neil Armstrong and Buzz Aldrin of *Apollo 11* are the first humans to walk on the moon.

April 19, 1971
The first space station, Salyut 1, is launched by the Russians.

December 3, 1973
US craft *Pioneer 10* is the first to fly by Jupiter.

March 29, 1974
US craft *Mariner 10* is the first to fly by Mercury.

July 17, 1975
US craft *Apollo18* and Russian *Soyuz 19* make the first international space rendezvous.

October 22, 1975
Russian craft *Venera 9* transmits the first images from the surface of Venus.

July 20, 1976
US craft *Viking 1* is the first to land successfully on Mars.

September 1, 1979
Pioneer 11 is the first to fly by Saturn.

April 12, 1981
Columbia, the first US space shuttle, is launched.

January 24, 1986
US craft *Voyager 2* is the first to fly by Uranus.

March 13, 1986
European craft *Giotto* takes the first close-up look at a comet.

August 24, 1989
Voyager 2 is the first craft to fly by Neptune.

April 24, 1990
The Hubble Space Telescope is launched.

September 15, 1990
US craft *Magellan* starts a three-year mapping program of Venus.

October 29, 1991
US craft *Galileo* makes the first flyby of an asteroid as it passes Gaspra.

July 13, 1995
Galileo arrives at Jupiter and releases a probe to enter its atmosphere.

July 4, 1997
US craft *Mars Pathfinder* and its *Sojourner* rover touch down on Mars.

November 20, 1998
Zarya, the first module of the International Space Station (ISS), is launched.

November 2, 2000
The first crew arrives to stay aboard the ISS.

February 12, 2001
The *NEAR* craft lands on asteroid Eros.

December 25, 2003
Europe's first interplanetary craft, *Mars Express*, orbits Mars.

June 30, 2004
US craft *Cassini* arrives at Saturn to study the planet and its moons. It releases *Huygens* to land on the moon Titan.

November 20, 2005
Japanese craft *Hayabusa* lands on asteroid Itokawa.

August 4, 2007
US craft *Phoenix* sets off for Mars, arriving in 2008.

March 18, 2011
US *Messenger* spacecraft becomes the first vehicle to orbit around Mercury.

August 6, 2012
US *Curiosity* rover lands in the Gale Crater on Mars.

August 6, 2014
European spacecraft *Rosetta*, carrying the lander *Philae*, enters orbit around Comet Churyumov-Gerasimenko.

July 14, 2015
US craft *New Horizons* makes the first flyby of the dwarf planet Pluto.

July 5, 2016
US *Juno* spacecraft enters orbit around Jupiter to survey the planet's polar regions.

September 15, 2017
Cassini ends its mission with a deliberate plunge into Saturn's atmosphere.

SPACE TRAVELERS

Since the first manned space mission in 1961, more than 560 people have traveled into space—27 on missions to the moon and the rest in orbit around Earth. To date, only Russia, China, and the United States have launched humans into space. However, humans are not the only space travelers. Animals such as dogs, monkeys, and spiders have all been sent into space to help with research.

❶ **Alan Shepard** was the second person, and first American, to travel into space.

❷ **Ulf Merbold,** from Germany, became the first European to fly aboard a space shuttle.

❸ **Jim Voss** set the record for longest spacewalk (8 hours 56 minutes) with Susan Helms.

❹ **Susan Helms** (see above).

❺ **Laika** was the first animal to orbit Earth. The Russian dog traveled in *Sputnik 2* in 1957.

❻ **Alexei Leonov** made the first spacewalk in March 1965. He spent 10 minutes in space secured to his *Voskhod 2* craft.

❼ **Eileen Collins** became the first female shuttle pilot in February 1995 and the first female shuttle commander in July 1999.

❽ **Yang Liwei** was the first Chinese astronaut (taikonaut). China's first manned space flight was launched in October 2003.

❾ **Svetlana Savitskaya** was the second woman in space and the first woman to spacewalk.

❿ **Michael Collins** was the third member of the *Apollo 11* mission in 1969. He orbited the moon, as Armstrong and Aldrin explored its surface.

⓫ **Dennis Tito** was the first space tourist. He paid $20 million for a six-day trip in 2001.

⓬ **Baker,** a squirrel monkey, was launched into space on May 28, 1959. She traveled with a rhesus monkey called Able.

⓭ **Eugene Cernan** was part of the *Apollo 17* mission in December 1972. He was the last person to walk on the moon.

⓮ **Neil Armstrong** was the first person to set foot on the moon. He spent 2 hours 35 minutes exploring the lunar surface.

⓯ **Yuri Gagarin** was the first person to fly into space. His trip in April 1961 took him once around Earth and lasted 108 minutes.

⓰ **Peggy Whitson** holds the record for the longest female spaceflight (289.2 days).

⓱ **Mike Melvill** was the first commercial astronaut. He piloted *SpaceShipOne* in June 2004.

⓲ **Valentina Tereshkova** was the first woman to fly into space. She made a three-day trip aboard *Vostok 6* in June 1963.

⓳ **Gennady Padalka** holds the record for the total time spent in space. In his five trips, he has clocked up 878.5 days in space.

⓴ **Sam** was a rhesus monkey who was sent into space in 1960 to test equipment that would be used in future manned flights.

㉑ **Valeri Polyakov** holds the record for the longest time spent in space during one trip. His record stands at 437.7 days.

㉒ **Bruce McCandless** made the first untethered spacewalk in February 1984.

㉓ **John Glenn** was the first American to orbit Earth, in 1962. He became the oldest space voyager in 1998, aged 77.

㉔ **Green tree frogs** were taken to the Mir space station in 1990.

㉕ **Buzz Aldrin** was the second person to set foot on the moon.

㉖ **Swordtail fish** traveled on board the space shuttle *Columbia* in 1998.

㉗ **Squirrel monkeys** and 24 albino rats were taken to Spacelab-3 in 1985.

㉘ **Arabella,** a spider, was sent to the Skylab space station in 1973. Once space-adapted, she spun perfect webs.

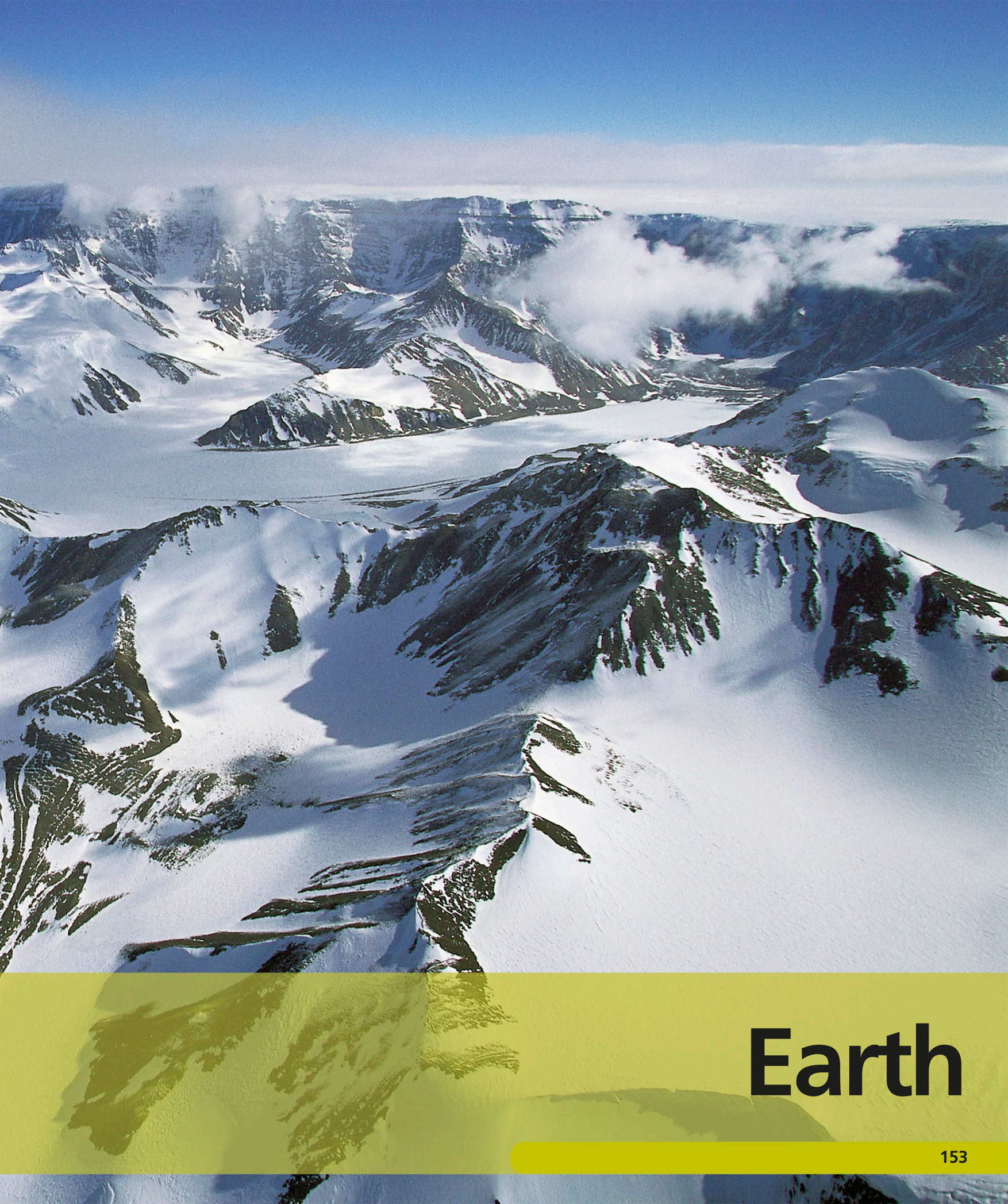
㉙ **Albino rats** (see above).

㉚ **Quail chicks** hatched from eggs on the Mir space station in March 1990.

㉛ **Belka and Strelka** became the first dogs to go into orbit and survive the journey in 1960.

㉜ **Ham** was the first chimpanzee to travel in space. In 1961, he was sent to test equipment that would be used in the first US manned space mission.

ANTARCTICA
The Transantarctic Mountains extend across Antarctica, dividing the continent into east and west. This region bordering the Ross Sea is known as Terra Nova and is famous for its spectacular ice caves.



Earth

PLANET EARTH

Earth was created some 4.6 billion years ago from a mass of iron-rich, rocky debris orbiting the sun. The rocks smashed into the young planet as meteorites and were welded together by heat generated from the energy of impact. The bombardment eventually generated so much heat that the whole planet melted. The heavy iron then sank toward the center to become Earth's core, while the lighter rocks formed the mantle and crust.

EARTH'S STRUCTURE

The planet is layered like a peach. Earth's rocky crust forms its thin skin, while the hot, mobile rock of the mantle is like the peach's juicy flesh. At the heart of the planet lies its metallic core, like the hard stone at the center of a peach.

❶ INNER CORE

The inner core is a heavy ball of solid iron and nickel. It is heated by nuclear reactions within Earth to 8,500°F (4,700°C), but the intense pressure at the core prevents it from melting.

❷ OUTER CORE

The solid inner core is surrounded by a fluid mass of molten iron, nickel, and sulfur. Swirling currents in the molten metal of the outer core generate Earth's magnetic field.

❸ LOWER MANTLE

The rocky mantle is 1,800 miles (2,900 km) deep and is heated to 6,300°F (3,500°C) at its base. Intense pressure stops it from melting, but rising heat keeps moving slowly.

❹ UPPER MANTLE

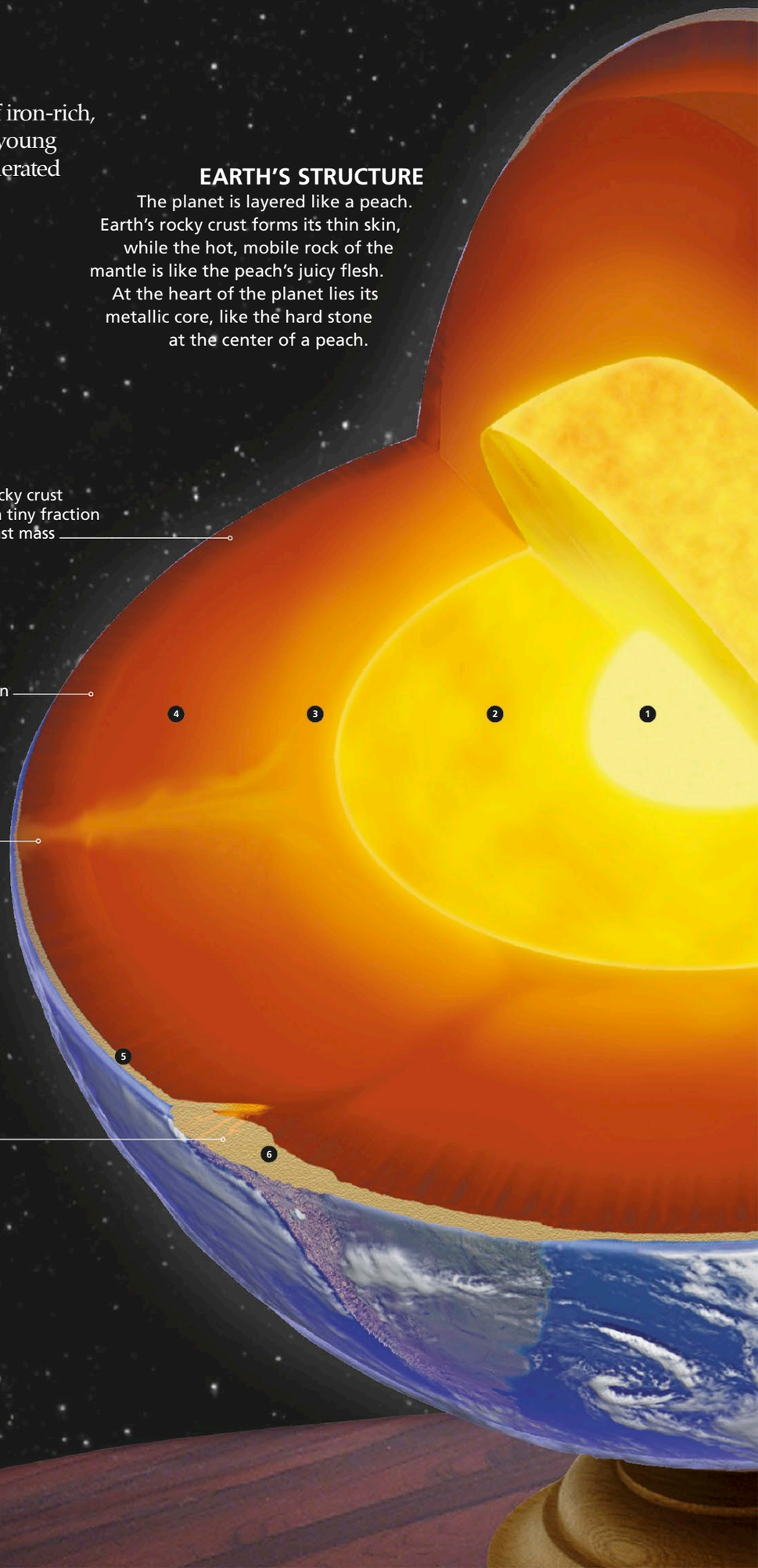
The upper mantle is heated to almost 1,800°F (1,000°C). Where movement in the mantle cracks the cool, brittle crust, reduced pressure makes the hot mantle rock melt and erupt from volcanoes.

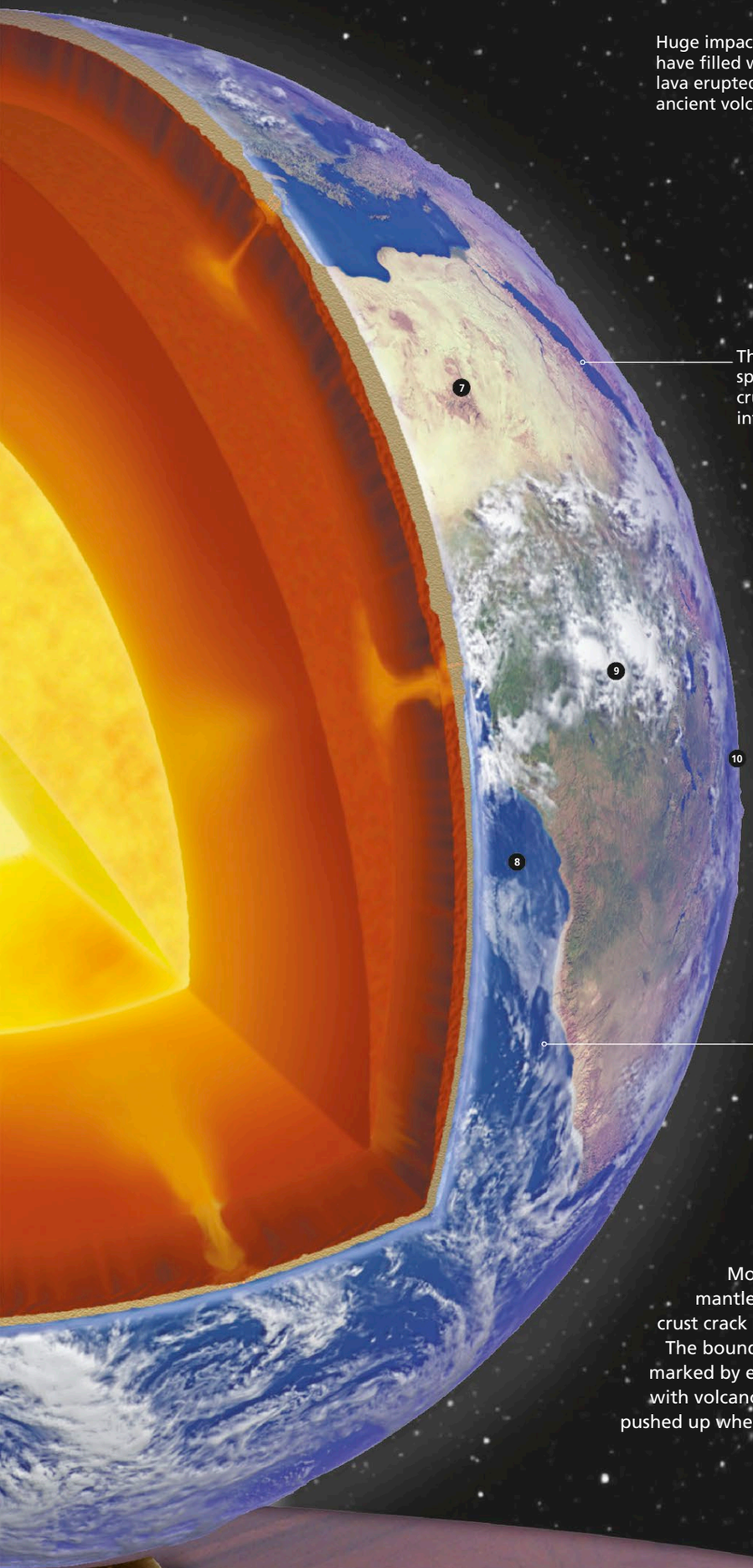
❺ OCEANIC CRUST

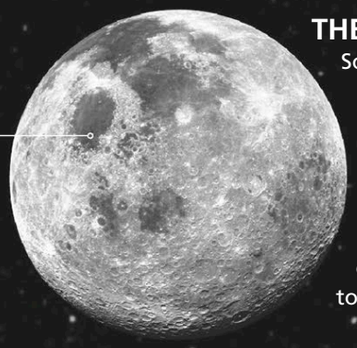
The crust between the continents is less than 7 miles (11 km) thick. It is made of heavy rock that erupts from the hot mantle at midocean ridges to form the bedrock of the ocean floors.

❻ CONTINENTAL CRUST

The lightest of Earth's rocks form vast slabs that "float" on the heavy mantle like huge rocky rafts. Up to 45 miles (70 km) thick, they rise above sea level to form the continents that we live on.







Huge impact craters have filled with dark lava erupted from ancient volcanoes

THE MOON

Soon after Earth formed, it was hit by a planet-sized asteroid that completely disintegrated. Most of its heavy metallic core melted into Earth, but the lighter rocky fragments drifted into orbit and eventually fused to form the moon.

The Red Sea is a spreading rift in Earth's crust that will widen into an ocean

❼ LAND SURFACE

Exposed to frost, wind, rain, and hot sunlight, the rocks at the land surface are broken down by weathering and erosion. This releases minerals that are vital to plants and other life.

❽ OCEANS

The low-lying basins between the continents are filled with water, to an average depth of 2.3 miles (3.7 km). Most of the water erupted from volcanoes as water vapor early in Earth's history.

❾ WEATHER SYSTEMS

The heat of the sun makes water evaporate from the oceans and rise into the lower atmosphere. The water forms swirling masses of cloud that spill rain onto the continents, allowing life to exist on land.

❿ ATMOSPHERE

Earth's mass gives it enough gravity to retain an atmosphere of nitrogen, oxygen, and other gases including carbon dioxide. This keeps Earth warm at night and shields it from dangerous radiation.

More than 70 percent of Earth's surface is covered by ocean water

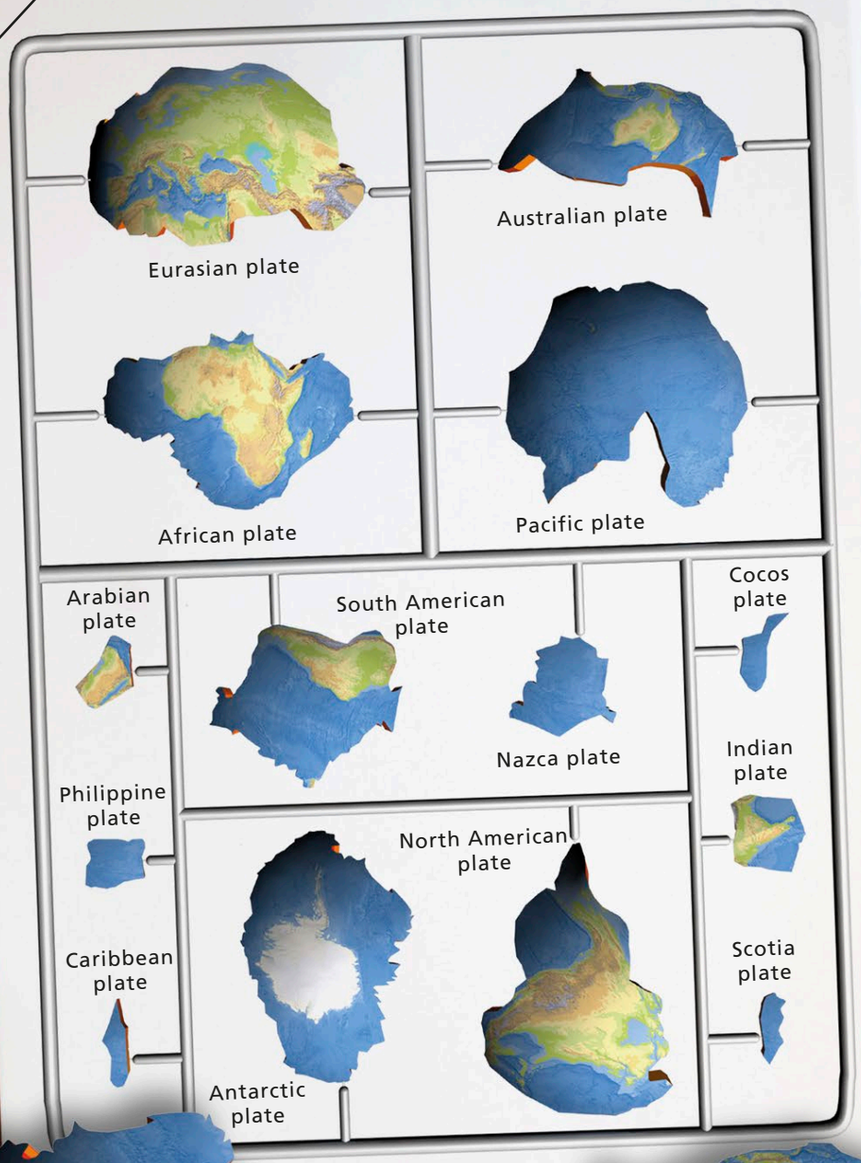
ON THE SURFACE

Movement in the thick, hot mantle has made the thin, cool crust crack into several huge plates. The boundaries of these plates are marked by earthquake zones dotted with volcanoes and mountain ridges pushed up where moving plates collide.

PLATE TECTONICS

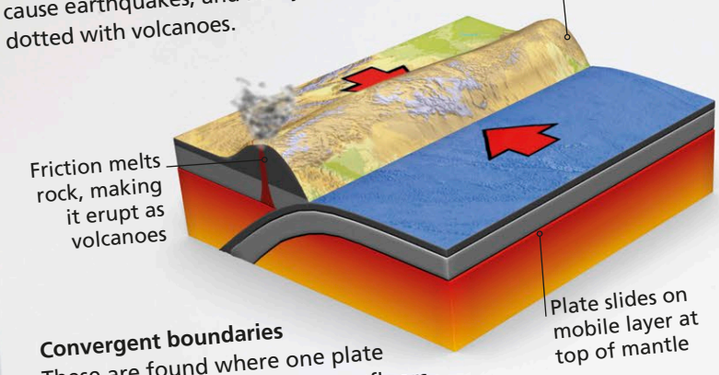
Earth's crust is the brittle shell of a deep layer of hot rock called the mantle. This is moving very slowly, driven by heat generated deep within the planet. The movement has made the crust crack into separate plates, which are being pulled apart in some places and pushed together in others. As they move, the plates make oceans larger or smaller and carry continents around the globe.

1

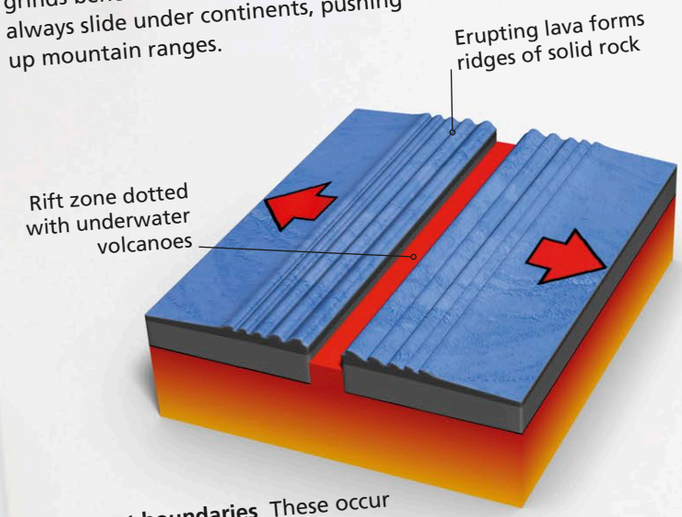


2 PLATE BOUNDARIES

At some plate boundaries, the plates are pulling apart, while at others they are pushing together. There are also places where one plate is sliding against another. All these movements cause earthquakes, and many boundaries are dotted with volcanoes.



Convergent boundaries These are found where one plate grinds beneath another. Ocean floors always slide under continents, pushing up mountain ranges.

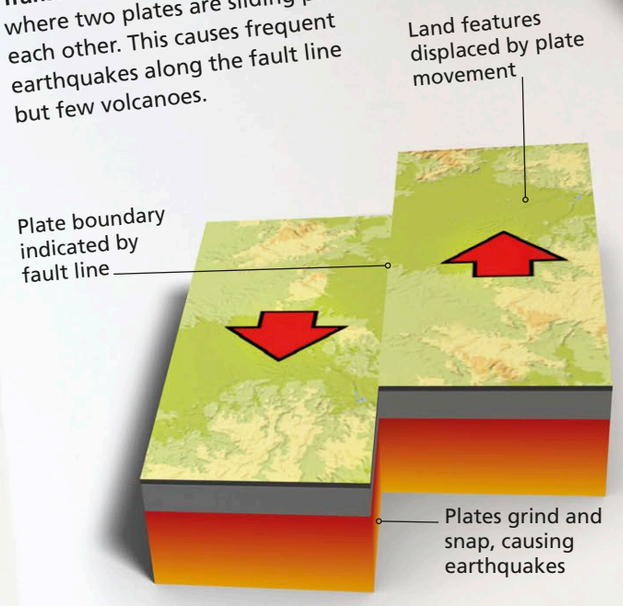


Divergent boundaries These occur where plates are pulling apart, usually on ocean floors. This allows hot mantle rock to erupt in the rift zone and solidify as new ocean floor.

◂ KIT OF PARTS

There are 15 large tectonic plates and almost 40 smaller ones. They form the ocean floors, and some of the largest carry continents. Continental plates are made of thicker but lighter rock than the ocean floors. The oceanic parts of the plates are always changing size and shape, but the continents, although moving, do not change so much.

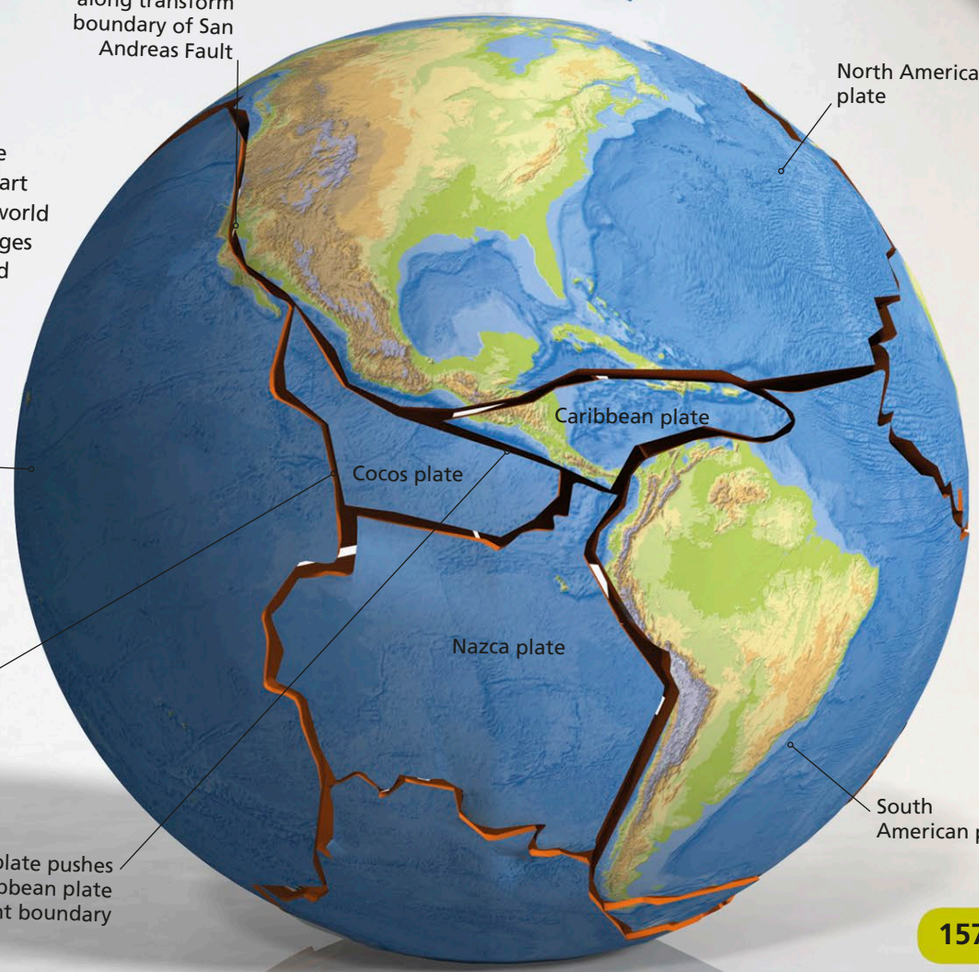
Transform boundaries These form where two plates are sliding past each other. This causes frequent earthquakes along the fault line but few volcanoes.



3

FRACTURED GLOBE ▸

The plates fit together to form the globe. Some plates are moving apart at divergent boundaries, but the world never gets bigger because the fringes of other plates are being destroyed at convergent boundaries. The relative movement of the Pacific, Cocos, and Caribbean plates shows how the plate boundaries are formed.



VOLCANOES

Volcanoes are the most spectacular and destructive of Earth's geological features. Most volcanoes lie along plate boundaries, where the slabs of rock (plates) that form Earth's crust meet. Opening rifts and the friction of plates grinding against each other make the hot rock beneath the crust melt and burst up through fissures (cracks). Volcanoes also occur over "hot spots" away from plate boundaries, caused by rising plumes of heat in the mantle beneath Earth's crust.

KILAUEA

The Hawaiian islands are a chain of volcanoes that have erupted from the Pacific Ocean floor as it slips over a hot spot in Earth's mantle. The oldest volcanoes in the north are now extinct, but Kilauea in the south is the most active volcano on Earth.

❶ ERUPTION
When Kilauea erupts, basalt lava and gas are forced up from deep within the volcano. Basalt lava is very fluid, so a lot of it just spills over the rim of the crater. Erupting gas can also cause explosive "fire fountains" of gas and red-hot lava, like this one.

❷ CRATER
Lava boils up through a vent to build up a cone of rocky debris. More eruptions make the inside of the cone collapse or even explode upward to create a roughly circular crater. Its almost sheer walls reveal layers of cinders, ash, and solidified lava.

❸ CONE
This small volcanic cone is just the summit of a huge, dome-shaped shield volcano, which rises all the way from the ocean floor 23,875 ft (7,277 m) below. The dome is built up by the fluid lava that erupts on Hawaii. Volcanoes that erupt stickier, less fluid lava have steeper sides.

❹ LAVA FLOW
The lava that erupts from Kilauea is extremely hot and is so fluid that it flows downhill away from the crater like a river of fire. Since 1983, the volcano has been erupting almost constantly, spilling lava over more than 40 sq miles (100 sq km).

❺ TYPES OF LAVA
Hawaiian lava is molten basalt rock pushed up from beneath the ocean floor. It is fluid because it contains very little silica (the mineral used to make glass). Other volcanoes erupt lava that is high in silica, which is much stickier and does not flow far.

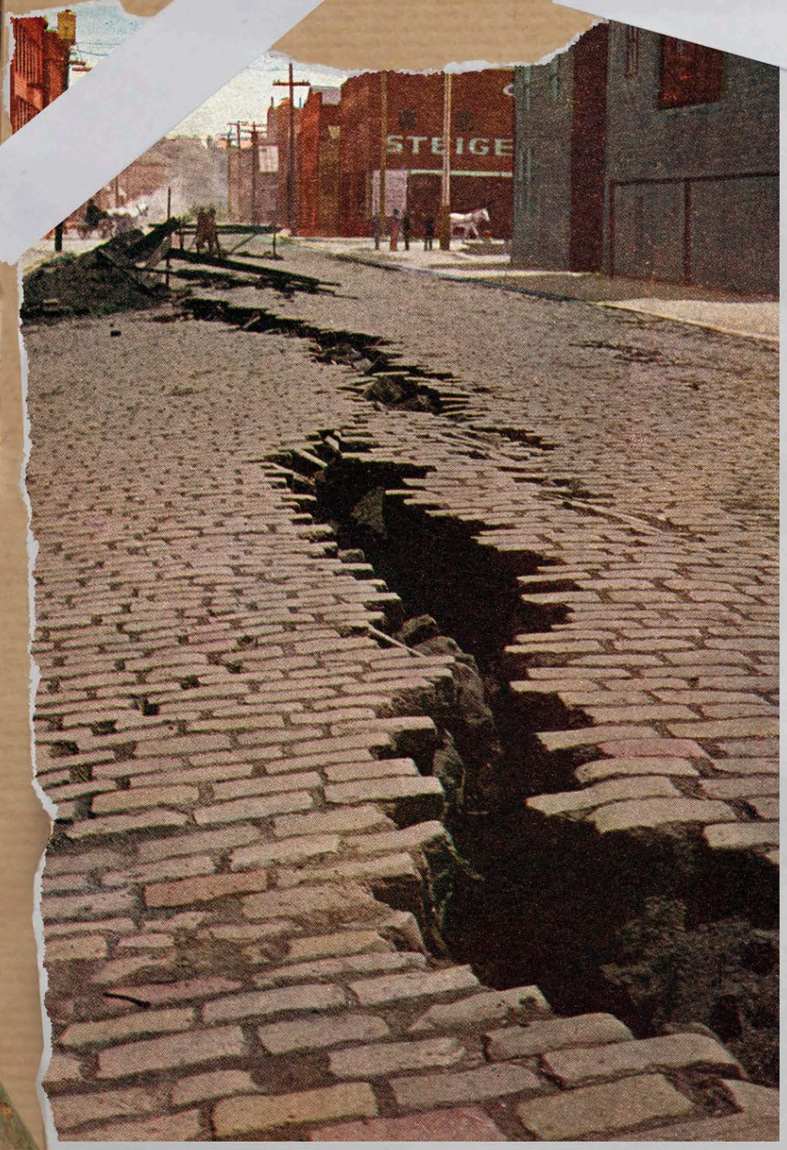
❻ LAVA TUBE
As the lava streams away from the active crater of Kilauea, the surface of the flow cools and hardens. Underneath, however, the hot lava keeps flowing. This creates "lava tubes" that extend to the coast, where the lava spills into the sea in clouds of steam.

EARTHQUAKES

The vast rocky plates of Earth's crust are always moving. Where the plates meet, the movement causes earthquakes. Frequent slight movement just causes tremors (shaking), but often the rocks on each side of a plate boundary lock together. The strain builds up, distorting the rocks until the locked section gives way. The rock springs back, often shifting several yards, and the shock of this can cause a catastrophic earthquake.

CHILE 1960

The biggest earthquake ever recorded struck Chile in 1960. It reached 9.5 on the Richter Scale, which was devised in 1935 by American scientist Charles Richter as a way of measuring earthquakes using instruments called seismographs.



SAN FRANCISCO 1906

The San Andreas Fault in California marks where the Pacific plate is sliding past North America. San Francisco is built on the fault line, and in 1906 the city was almost destroyed when the fault slipped 20 ft (6 m) and triggered disastrous fires.

ALASKA 1964

On March 27, 1964, the Pacific Ocean floor slid 65 ft (20 m) beneath Alaska in a few minutes, causing a colossal earthquake. So few people live in this remote region, however, that only 125 lost their lives.

MEXICO CITY 1985

Mexico's capital city is built on the dried-out clay bed of an ancient lake. The earthquake that hit the city in 1985 made the clay shake like jelly, making the shock waves six times as destructive. More than 400 multistory buildings in the city were shaken to the ground, and at least 9,000 people died.

KOBE 1995

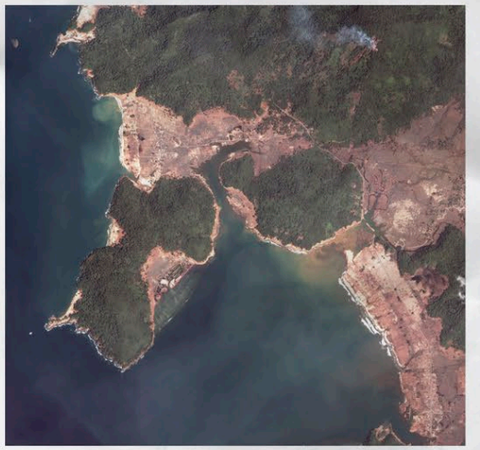
Japan was created by intense ground movements in the western Pacific, and it has more earthquakes than almost anywhere else. In 1995, an earthquake wrecked the city of Kobe, destroying this elevated highway and killing 6,433 people.

INDONESIA 2006

In 2006, a serious earthquake struck the Indonesian island of Java, wrecking up to 135,000 houses and killing at least 5,780 people. It also damaged the ancient Hindu temple of Prambanan, a World Heritage Site, but did not destroy it.

TSUNAMI 2004

The Asian tsunami that killed more than 283,000 in 2004 was caused by an earthquake on the ocean floor off Sumatra. The shock sent huge waves racing across the Indian Ocean, devastating communities all around its shores.



Above left: the city of Banda Aceh, Sumatra, Indonesia, as it was in April 2004

Left: the same area pictured in January 2006, after the tsunami had struck

MOUNTAINS

The world's mountains were raised by the titanic forces that keep the plates of Earth's crust moving. Where the plates grind together, the edges of continents are forced up into high, folded ridges, like the Andes Mountains in South America. Hot rock deep beneath the surface may erupt through cracks in the folded rock to form volcanoes. These also erupt where the crust is being torn apart and over "hot spots" deep within Earth. The landscape below has been created from images of the highest peaks on each continent and one that rises from the depths of the Pacific Ocean.

❶ MOUNT EVEREST

The world's highest peak, Everest lies 29,035 ft (8,850 m) above sea level. It is part of the Himalayas, a range of fold mountains created by the collision of India with Asia 50 million years ago. India is still moving north, so the Himalayas are still rising.

❷ MOUNT ACONCAGUA

The Pacific Ocean floor is plunging beneath South America, rucking up its western edge to form the rugged, earthquake-prone mountains of the Andes. Mount Aconcagua is the highest peak, at 22,834 ft (6,959 m).

❸ MOUNT MCKINLEY

Rising 20,321 ft (6,194 m) above sea level, Mount McKinley in Alaska is the highest peak of the North American Western Cordillera. Its isolation and bulk make it one of the world's most spectacular mountains.

❹ MOUNT KILIMANJARO

The highest mountain in Africa, Kilimanjaro is actually a colossal volcano with three volcanic cones. The highest peak on the tallest cone, Kibo, rises 19,340 ft (5,895 m) above sea level. The other volcanic cones are Mawenzi and Shira.

❺ MAUNA KEA

The highest point on Hawaii is the top of a huge volcano that rises 33,000 ft (10,000 m) from the Pacific Ocean floor. So although its peak is only 13,796 feet (4,205 m) above sea level, it is the biggest mountain on Earth.

❻ VINSON MASSIF

The most remote mountains on Earth lie on the frozen continent of Antarctica. Overlooking the vast mass of the Ronne Ice Shelf, Vinson Massif in the Ellsworth range is the highest point at 16,067 ft (4,897 m).

❼ MONT BLANC

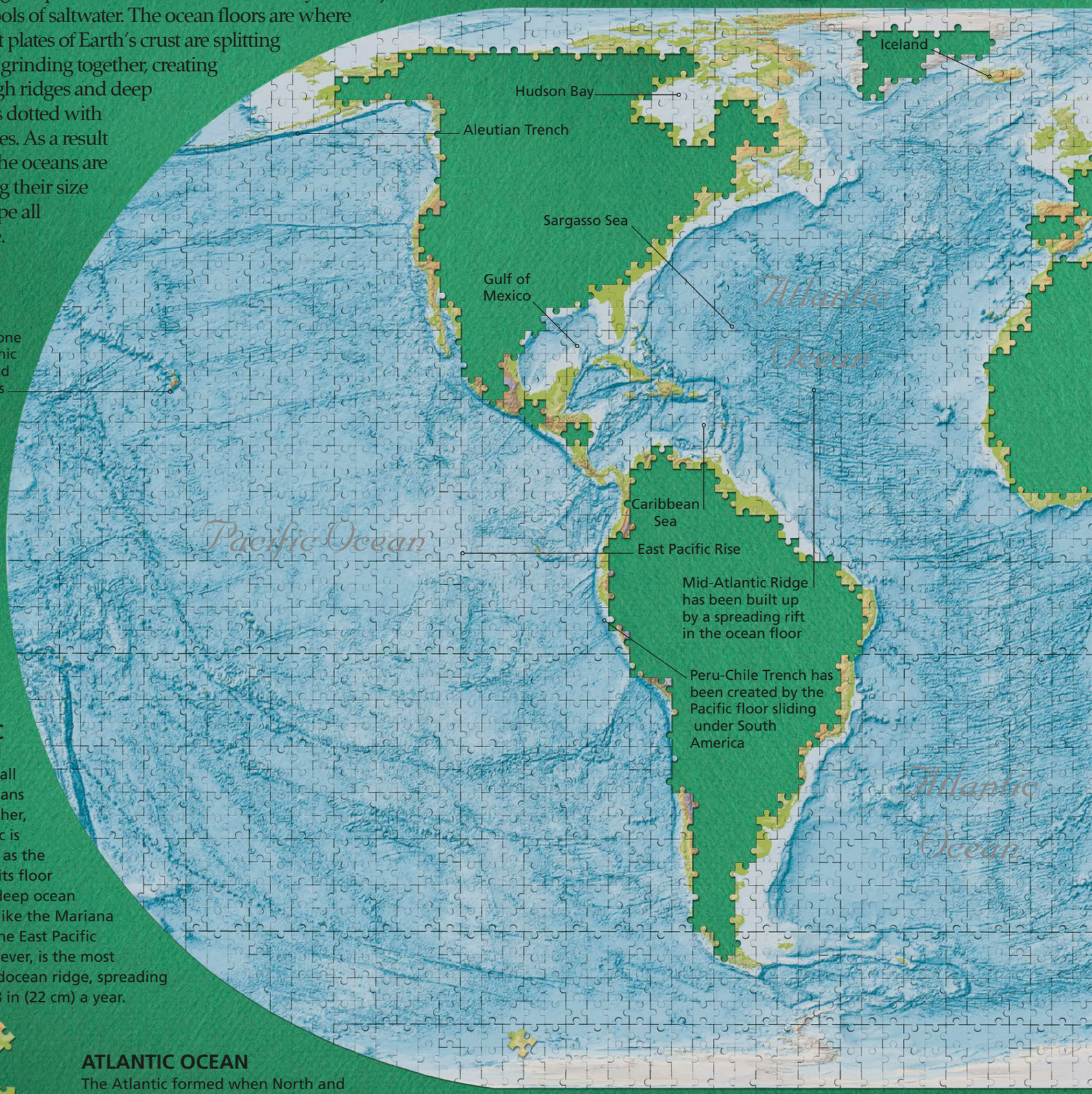
The folded ridges of the European Alps have been raised by the northward movement of Africa. Mont Blanc is the highest peak at 15,774 ft (4,808 m), but since its summit is a dome of ice, its height varies from year to year.

❽ AORAKI (MOUNT COOK)

The highest peak in New Zealand, Aoraki's name means "cloud piercer" in the native Maori language. The mountain is also known as Mount Cook. Now 12,284 ft (2,744 m) high, Aoraki was 33 ft (10 m) higher before a landslide in 1991.

OCEANS

The oceans cover more than two-thirds of the surface of Earth, with an average depth of 2.4 miles (3.8 km), but they are not just huge pools of saltwater. The ocean floors are where the great plates of Earth's crust are splitting apart or grinding together, creating long, high ridges and deep trenches dotted with volcanoes. As a result of this, the oceans are changing their size and shape all the time.



PACIFIC OCEAN

As big as all other oceans put together, the Pacific is shrinking as the edges of its floor slip into deep ocean trenches like the Mariana Trench. The East Pacific Rise, however, is the most active midocean ridge, spreading at up to 8 in (22 cm) a year.

ATLANTIC OCEAN

The Atlantic formed when North and South America split from Europe and Africa and gradually moved west. The ocean is still growing as new ocean floor is created at the Mid-Atlantic Ridge. The ridge breaks the surface in the north to form Iceland, with its volcanoes and geysers.

ARCTIC OCEAN

Most of the Arctic Ocean is covered by thick floating ice in winter. A lot of this melts in spring, allowing sunlight to reach the cold waters and fuel the growth of ocean life. The sea near the North Pole stays frozen in summer, but the area covered by ice is shrinking every year because of global warming.

INDIAN OCEAN

This mainly tropical ocean is notorious for the tsunami that swept across it from Sumatra in 2004. It had a serious impact on nearby coasts and low-lying coral islands like the Maldives, which crown the peaks of an underwater mountain ridge extending south from India.

SOUTHERN OCEAN

With no obvious northern boundaries, the Southern Ocean forms a ring of cold, stormy water around Antarctica. Ice covers a vast area in winter, and the giant icebergs that break off Antarctic glaciers and ice shelves sometimes drift far to the north.

ROCKS AND MINERALS

Rocks are mixtures of natural chemical compounds called minerals, which form crystals with distinctive shapes. There are three main types of rocks. Igneous rock is formed when molten rock cools and hardens, a metamorphic rock is one that has been changed by heat or pressure, and sedimentary rock is generally made from fragments of rock cemented together.

❶ **Slate** This dark rock is created when sedimentary shale is put under intense pressure. It forms thin sheets that can be cut into squares and used for roofing.

❷ **Cockscomb barite** This whitish mineral is often found in veins running through rocks. Its crystals form clusters that can resemble cockscombs (roosters' head crests).

❸ **Schist** Like slate, schist is created by pressure and heat, which transforms a soft sedimentary rock into a very much harder metamorphic rock.

❹ **Chalk** A type of limestone, chalk is built up from the remains of tiny marine organisms that sank to the bottom of a tropical sea during the age of dinosaurs.

❺ **Marble** Hard and usually pale, marble is a metamorphic form of limestone. It can be carved and polished into statues, and decorative slabs are used in architecture.

❻ **Calcite** The main mineral in limestone and marble, calcite forms the stalactites and stalagmites seen in limestone caves.

❼ **Limestone** All limestones are made of chalky minerals, particularly calcite. They are easily dissolved by rainwater, creating extensive cave systems.

❽ **Halite** Formed by the evaporation of salt lakes, halite is rock salt—the mineral that we use to flavor our food.

❾ **Biotite** Dark brown biotite is a type of mica, a mineral found in most granites and schists. Its platelike crystals resemble thin, flaky sheets of hard plastic.

❿ **Eclogite** A dense, heavy metamorphic rock formed deep beneath Earth's surface, eclogite contains bright green pyroxene and glittering red garnet minerals.

⓫ **Tremolite** Thin, transparent, fibrous-looking crystals of tremolite form from limestones that have been subjected to intense heat deep underground.

⓬ **Beryl** This very hard mineral forms transparent, often greenish crystals that can be cut to create emeralds and aquamarines.

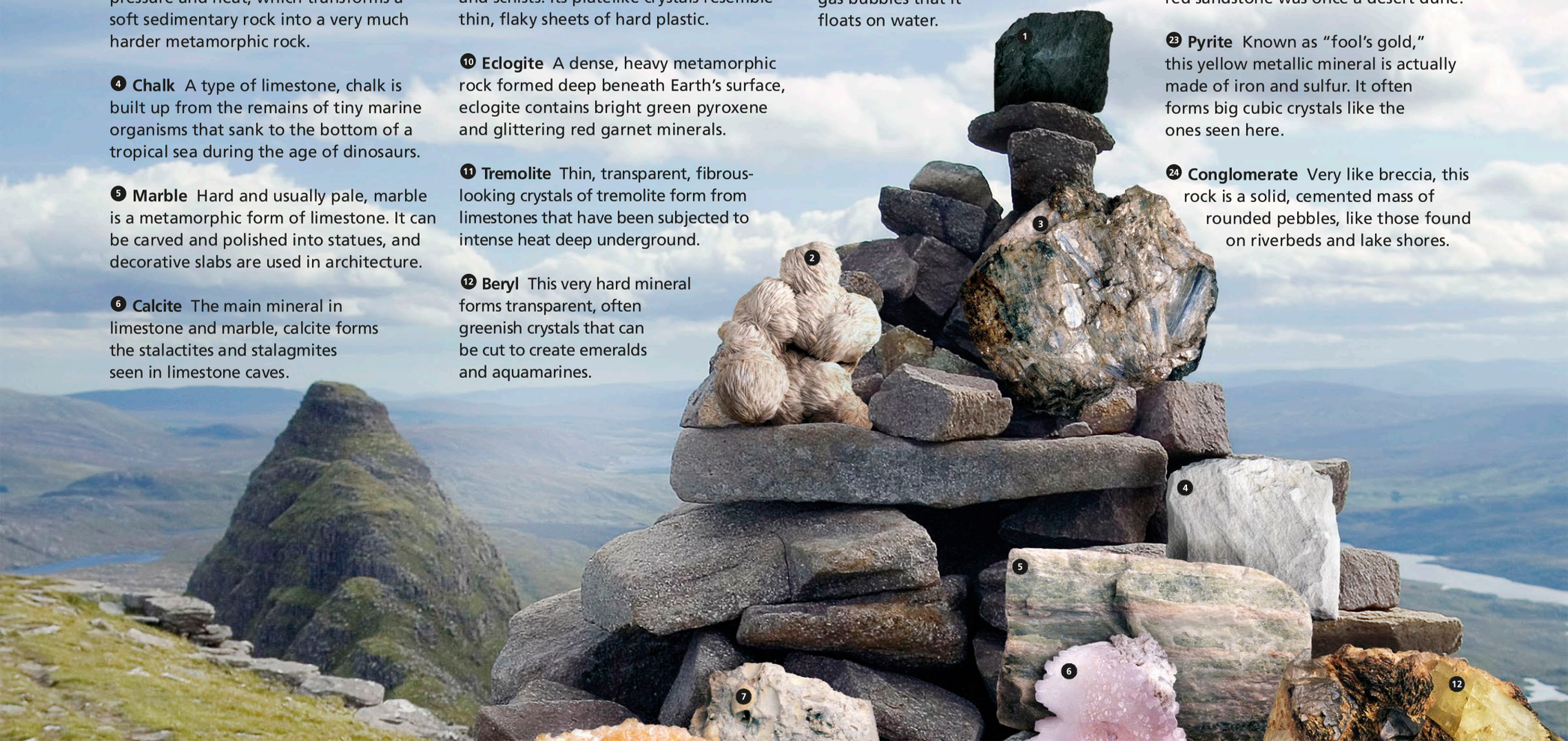
⓭ **Granite** One of the main rocks that form continents, granite results from molten rock cooling slowly deep underground to form big quartz, feldspar, and mica crystals.

⓮ **Breccia** This sedimentary rock is made of broken, sharp-edged rock fragments cemented together by finer particles.

⓯ **Obsidian** Also known as volcanic glass, this shiny black or dark green rock is formed when molten lava cools too quickly to form crystals.

⓰ **Gabbro** This is a coarse, dark, iron-rich, crystalline rock that makes up much of the deep ocean floor.

⓱ **Pumice** Gas erupting from volcanoes often forms bubbles inside cooling lava. This can then form pumice, which has so many gas bubbles that it floats on water.



⓲ **Corundum** This dull-looking stone is a type of corundum, the hardest mineral after diamond. Its crystals are used to make rubies and sapphires.

⓳ **Albite** A pale, sodium-rich form of feldspar, albite is a common ingredient of granite, visible as big, blocky crystals that glint in the sunshine.

⓴ **Graphite** Made of pure carbon—like diamond—graphite is a soft, metallic mineral that leaves a dark streak. It is used to make the "lead" in pencils.

㉑ **Basalt** Heavy, dark basalt is the fine-grained form of gabbro, created when iron-rich lava from oceanic volcanoes cools quickly, often underwater.

㉒ **Sandstone** Sand cemented together by other minerals forms sandstone. This red sandstone was once a desert dune.

㉓ **Pyrite** Known as "fool's gold," this yellow metallic mineral is actually made of iron and sulfur. It often forms big cubic crystals like the ones seen here.

㉔ **Conglomerate** Very like breccia, this rock is a solid, cemented mass of rounded pebbles, like those found on riverbeds and lake shores.

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Amethystine spinel is named for its amethyst color.

Golden sapphire is a golden form of blue sapphire.

Brown tourmaline is one of hundreds of the gem's colors.

Chrysoberyl can be honey yellow to mint green.

Green beryl is a pale variety of emerald.

Danburite is colorless, yellow, green, or brown.

Danburite is named for the US city of Danbury, CT.

Mauve spinel is mined in Myanmar (Burma), like most spinels.

Amethystine sapphire is made of hard corundum.

Pied tourmaline has two colors in one crystal.

Yellow beryl is tinted with iron and uranium.

Citrine is a warm yellow type of quartz.

Garnet was a favorite with ancient civilizations.

Andalusite glints with green and orange.

Red spinel is often used in place of rubies.

Ruby is the same mineral as sapphire but red.

Red tourmaline that looks like ruby is called rubelite.

Chrysoberyl is valued as a good luck charm.

Amethyst is always violet or purple.

Topaz is said to dispel sadness, fear, and anger.

Opal has changing colors caused by scattered light.

Opal matrix is polished rock with veins of opal.

Blue zircon is the most desirable form of zircon.

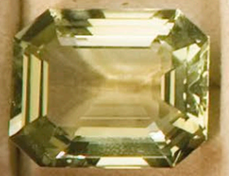
Tanzanite is named after Tanzania where it is found.

Green tourmaline can resemble a fine emerald.

Iolite looks like different colors from different angles.

Green tourmaline is sometimes called verdelite.

Emerald catseye has a pale stripe.



Green beryl is a paler form of emerald.

Chrysoprase is prized for its apple color.

Catseye quartz has a pale, glowing streak or "cat's eye."

Carbuncle is a polished, domed form of garnet.

Tiger eye is striped with yellow and brown.

Albite is always white.

Moonstone is a magical gem in India.

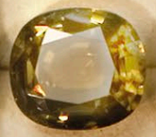
Zircon is one of the heaviest gemstones.

Star sapphire has a star pattern on its surface.

Amethyst is a violet form of common quartz.

Tourmaline has more colors than any other gem.

Green zircon is more rare than the blue form.



Brown zircon is one of many color varieties.

Colorless topaz can be mistaken for a diamond.

GEMS

The natural minerals that make up rocks can form glassy crystals, which can be cut into glittering gems. Many are extremely hard and contain different impurities that tint gems, such as sapphire, tourmaline, and topaz, a sparkling array of colors. They can be extremely valuable. The gem collection shown here is worth almost a million dollars.

Lead scuba weights

Galena (lead ore)

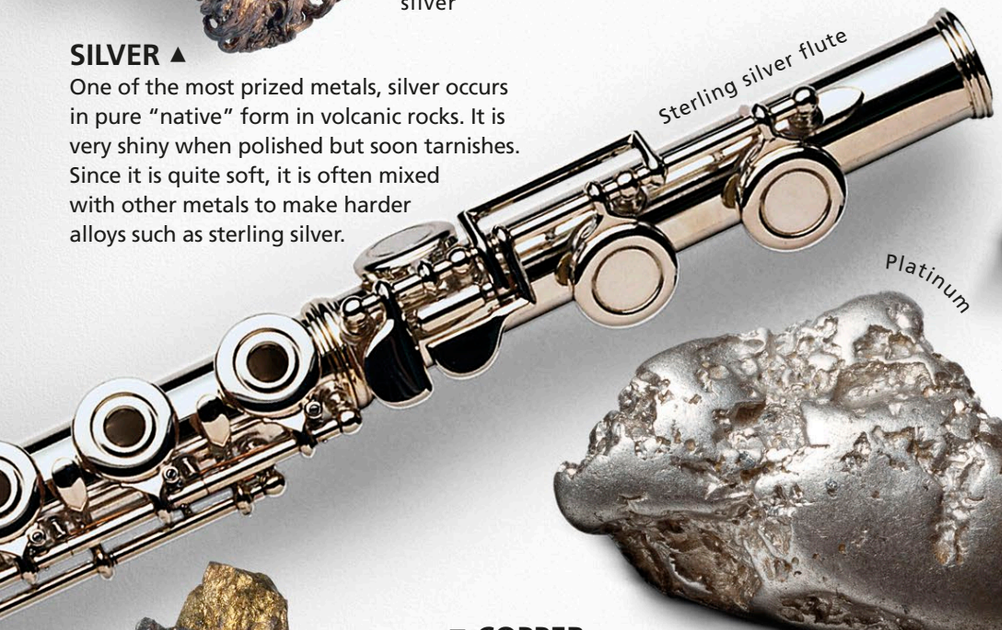
◄ LEAD
Very dense and heavy, lead is a dark, soft metal with a low melting point, which makes it easy to shape. It is widely used in lead-acid car batteries but also for heavy weights and roofing. The main lead ore is galena, a compound of lead and sulfur that forms big crystals.

METALS

Metals are minerals with a closely packed atomic structure, which makes them excellent conductors of electricity and heat. Most are also strong, workable materials, ideal for making a huge range of artifacts. Pure metals are elements, with only one type of atom in their chemical structure. In nature, many are mixed with rocks or combined with other elements to form chemical compounds. These ores must be mined and processed to extract the pure metals.

Native silver

SILVER ▲
One of the most prized metals, silver occurs in pure "native" form in volcanic rocks. It is very shiny when polished but soon tarnishes. Since it is quite soft, it is often mixed with other metals to make harder alloys such as sterling silver.

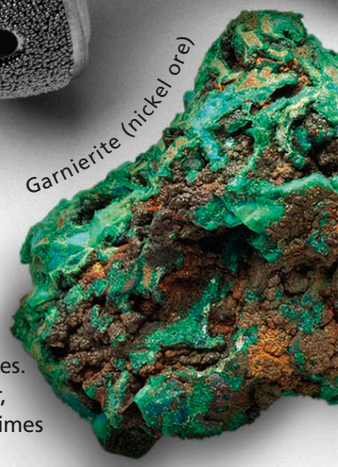


Sterling silver flute

The nickel in the stainless steel makes this hip joint corrosion-proof

Platinum ring

Platinum



Garnierite (nickel ore)

◄ PLATINUM
A beautiful, very heavy metal, platinum is often used in jewelry because, like gold, it never tarnishes. It is tougher than gold, and rarer, so it is more precious. It is sometimes found as nuggets of pure metal.

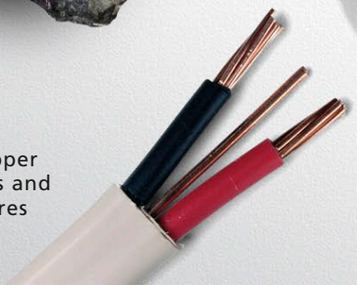
Chalcopyrite (copper ore)

▼ COPPER
Copper is a soft metal, often alloyed with zinc to make brass, or with tin to form bronze—both much harder. A good conductor, it is widely used for electric wire. Its main ore is chalcopyrite, a compound of copper, iron, and sulfur.

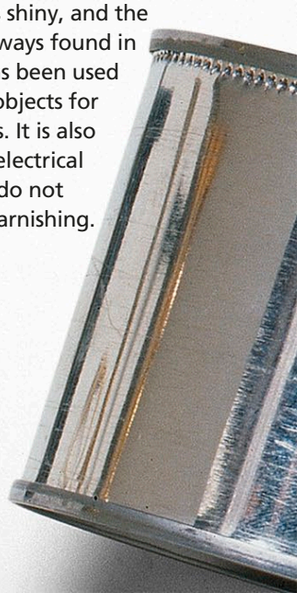
Gold nugget

▼ GOLD
Easily worked, always shiny, and the only metal that is always found in pure form, gold has been used to make precious objects for thousands of years. It is also used to make electrical contacts that do not degrade by tarnishing.

Gold audio connectors



Copper pipes and wires



A deep-sea submersible

Aluminum baking foil

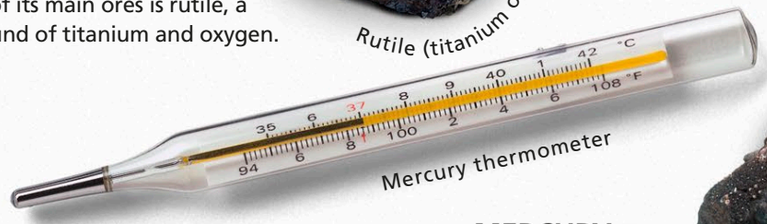
Bauxite (aluminum ore)

ALUMINUM ▶
Abundant and resistant to corrosion, lightweight aluminum is widely used for foil, cans, and in aircraft. Its ore, bauxite, is a rock that contains many aluminum compounds.

TITANIUM ▶
Light yet very strong, titanium is often combined with other metals to make lightweight alloys used in aircraft, spacecraft, and the pressure-proof capsules of deep-sea submersibles. One of its main ores is rutile, a compound of titanium and oxygen.

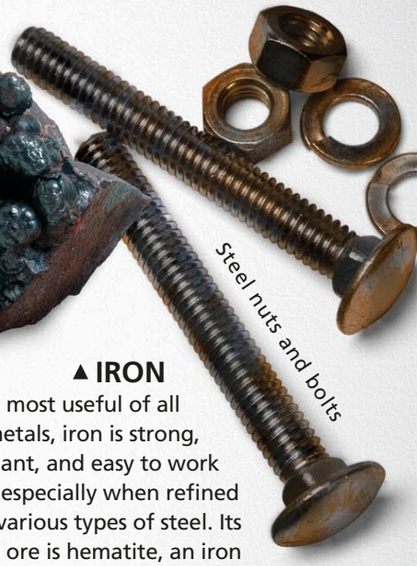
Rutile (titanium ore)

Stainless steel hip replacement



Mercury thermometer

Hematite (iron ore)



Steel nuts and bolts

MERCURY ▼
The only metal that is liquid at room temperature, mercury is most familiar as the silvery contents of a medical thermometer. Its ore, cinnabar, is a colorful compound of mercury and sulfur found near volcanoes.

Cinnabar (mercury ore)

▲ IRON
The most useful of all metals, iron is strong, abundant, and easy to work with, especially when refined into various types of steel. Its main ore is hematite, an iron oxide—the same thing as rust.

◀ NICKEL
Rarely used on its own, nickel is often alloyed with iron to make stainless steel. This is used for all kinds of applications, from knives and forks to replacement hip joints. Nickel is also alloyed with silver to make coins.

Cassiterite (tin ore)

Tin can

TIN ▲
Well known for its use in tin cans—which are actually tin-plated steel—tin is widely used in electronic components because of its high electrical conductivity. It is also alloyed with lead to make the solder used to assemble electronic circuits.

Sphalerite (zinc ore)

Galvanized chain

ZINC ▶
Zinc is a white metal that is alloyed with copper to make brass. Its main use, however, is plating or "galvanizing" steel to make it rustproof. Its main ore is sphalerite, a sparkling mineral that is a compound of zinc, iron, and sulfur.

Resembling wood lice, trilobites lived on seabeds throughout the Paleozoic Era

PALEOZOIC ERA (ANCIENT LIFE)

Life began in the Precambrian Era, more than 3.5 billion years ago, but for most of that time, life was restricted to single-celled organisms like bacteria. The start of the Paleozoic Era 540 million years ago saw an explosion of multicellular life, such as marine arthropods, mollusks, and primitive relatives of fish.

Sea lilies were plant-shaped relatives of starfish, attached to the seabed by stalks

Lobe-finned fish are the cousins of all modern animals with four legs

FOSSILS

The remains, impressions, or traces of organisms (such as plants and animals) that have been preserved in the rocks are known as fossils. The process of fossilization generally takes millions of years, and since special circumstances are needed for fossils to form, only a tiny proportion of Earth's organisms have been fossilized. It is not always easy to date fossils absolutely, so the paleontologists who find, analyze, and identify fossils usually assign them to named eras and periods. These cover the major phases in the long history of life on Earth.

This model of a *Deinonychus* skull helps paleontologists understand the biology of this predator

Finely detailed fossils show the feathers of *Archaeopteryx*, one of the first-known birds

Whole animals such as insects are preserved in amber, or fossilized tree resin

Fossil ammonites (prehistoric sea creatures) were recorded in this book more than 100 years ago

Familiar animals, like this dragonfly, were already common 150 million years ago

MESOZOIC ERA (MIDDLE LIFE)

Beginning 252 million years ago, this was the age of the dinosaurs, when giant reptiles stalked the land, pterosaurs swooped through the skies, and marine reptiles such as ichthyosaurs swam alongside squidlike ammonites. Flowering plants and small mammals also appeared on land. The era ended with a mass extinction 66 million years ago.

CENOZOIC ERA (RECENT LIFE)

Nonbird dinosaur fossils do not appear in rock formed less than 66 million years ago in the Cenozoic Era, showing that they had died out by that time. Yet mammal fossils become more varied and include early relatives of humans, which date back to 6–7 million years ago. The first true humans appeared about a million years later.

PALEONTOLOGY

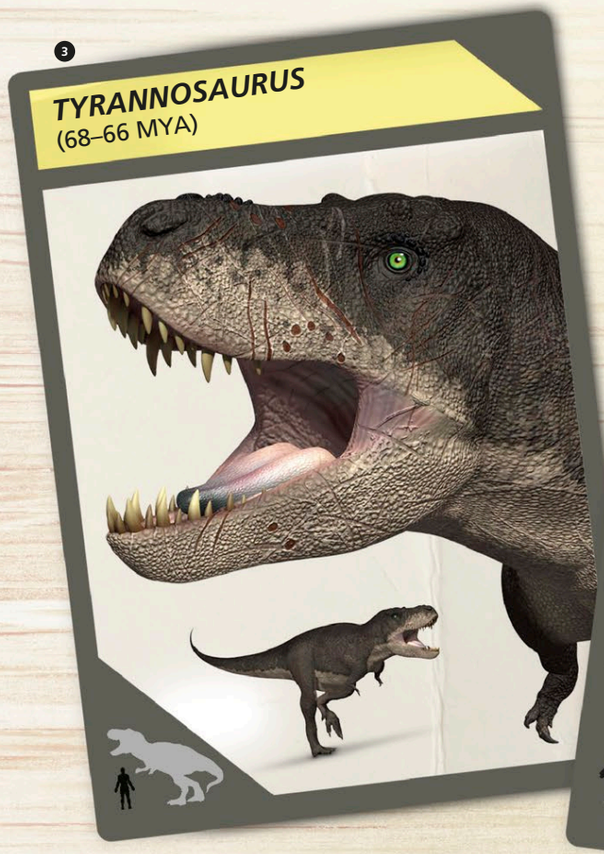
The word "paleontology" means the study of ancient life, preserved as fossils. But paleontologists also study nonbony life forms such as mollusks, plants, and even bacteria. Their work involves carefully removing, cleaning, and preserving the fossils, as well as identifying them and recording their features. Special tools ranging from hammers to medical scanners help them prepare and interpret their finds.

FOSSILIZATION

Normally only the hard parts of living things, such as shells and bones, survive as fossils. Over millions of years, these become impregnated with minerals, so they become stony. Often the original shell or bone disappear, leaving a mold later filled by another mineral. Rarely, soft body parts such as feathers may leave detailed impressions in fine-grained rock.

DINOSAURS

Long ago, life on Earth was dominated by the dinosaurs, a group of reptiles that included huge, lumbering plant eaters and fearsome, agile hunters. Except for the birds, dinosaurs became extinct 66 million years ago (MYA), but their fossilized remains survive in the rocks of ancient continents, allowing scientists to reconstruct what they looked like and how they lived.



❶ *STRUTHIOMIMUS*

Standing taller than a man, this agile, fast-running dinosaur was more like an ostrich than a typical reptile. It had no teeth in its long jaws but had a beak made from keratin, like birds. It was probably a herbivore.

❷ *ALLOSAURUS*

Although it probably looked very like *Tyrannosaurus*, the fossils of this massive meat eater have been found in rocks that are at least 70 million years older. This time span is longer than the period that separates the last dinosaurs from our own time.

❸ *TYRANNOSAURUS*

The biggest of the tyrannosaurs, *Tyrannosaurus rex* grew to 39 ft (12 m) and had thick, banana-shaped teeth up to 6 in (15 cm) long. Its fossilized remains have been found in rocks in North America, notably in Montana and South Dakota.

❹ *VELOCIRAPTOR*

Found in Mongolia, the fossil bones of this smallish dinosaur are similar to those of the first birds, and recent research shows that it may have had feathers. It was an agile, high-speed hunter that probably jumped on its prey and gripped with its hooked claws.

❺ *SAUROLOPHUS*

This plant eater had a bony crest on its skull that may have supported an ornamental crest. Fossils from Asia have longer crests than fossils found in America, showing that there were at least two different species.

❻ *IGUANODON*

Iguanodon was a large, bulky herbivore with a strange spike on its thumb. Scientists are still unsure how this spike was used.

❼ *STEGOSAURUS*

Stegosaurus fed on plants in what is now North America and Europe, 155–150 million years ago. Scientists still puzzle over the function of the huge bony plates on its back, which are not attached to the backbone. Two pairs of spikes on the tail were likely used to ward off predators.

❽ *TRICERATOPS*

The bony neck shield and three sharp horns of *Triceratops* were used in combat with other *Triceratops*. Judging from fossilized bones found in North America, the animal grew to at least 30 ft (9 m) long.

❾ *DIPLODOCUS*

This giant dinosaur lived in what is now North America at the same time as *Allosaurus* but used its long neck to browse over a large area. It was up to 90 ft (27 m) long, with a small head and whiplike tail.

❿ *OVIRAPTOR*

Similar to the larger *Struthiomimus*, this birdlike dinosaur had short powerful jaws and possibly a beak. It was earlier thought to have been an "egg thief" because the first fossil specimen was found on a nest of dinosaur eggs, and scientists believed that it may have died trying to steal them. However, further research suggests that it is likely that the *Oviraptor* was just incubating its own nest, not stealing the eggs.

HAILSTONES ►

Big thunderclouds contain updrafts that carry raindrops to heights where they freeze. The pellets of ice fall through the cloud but are carried up again so more ice freezes onto them. This can happen many times, building up hailstones that can be bigger than golf balls.

◄ LIGHTNING

Ice crystals tossed around inside a thundercloud can charge the cloud with electricity like a giant battery. Eventually the charge is released as a colossal spark of lightning, which heats the air along its path to about 50,000°F (30,000°C) in a split second.

▲ THUNDERSTORMS

Hot sunshine causes water to evaporate and rise into the air, where it cools and forms clouds. Some clouds build up to immense heights of 9 miles (15 km) or more. They contain a huge weight of water that is eventually released in dramatic thunderstorms of torrential rain.

FLOODS ►

Heavy rain can swell rivers until they overflow their banks, flooding nearby low-lying land. The water may rise slowly, but it can also surge down valleys in sudden "flash floods" that sweep everything before them. Either way, the flood water can wreck homes and even swamp cities.

TORNADOES ►

Thunderclouds are built up by rising warm, moist air that spirals up into the cloud. Sometimes this can develop into a tight, swirling vortex of rising air, called a tornado. Wind speeds inside the vortex can exceed 300 mph (500 km/h), and the powerful updraft can easily rip the roof off a house.

ICE STORMS ►

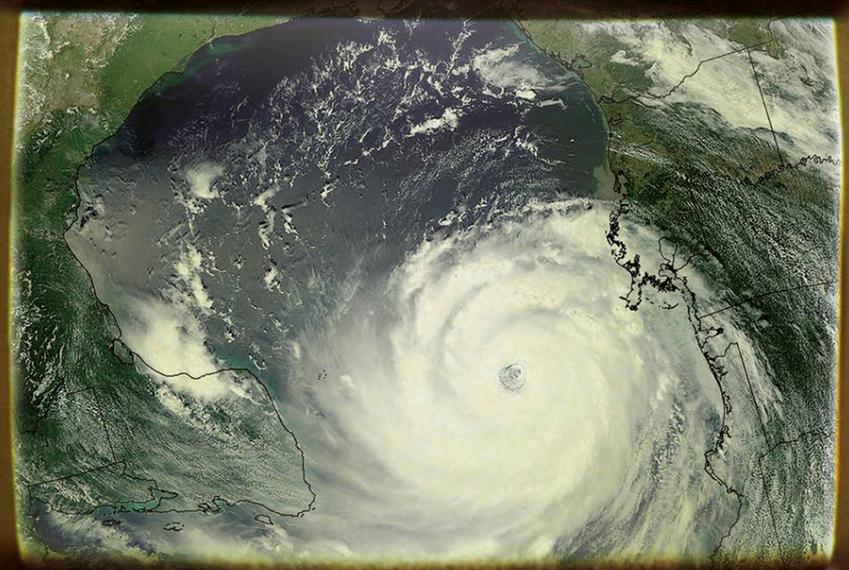
Freezing winter weather is normal in many regions, but freak conditions can sometimes cause unusually destructive ice storms. If moist air is swept over a very cold region, falling rain may freeze where it lands to form thick ice. This can bring down power lines, paralyze rail networks, and turn roads into death traps.

◄ HURRICANES

The most devastating weather occurs over tropical oceans, where intense heat creates huge storm clouds that revolve around zones of very low air pressure. Winds spiral into the center at 185 mph (300 km/h) or more, heaping ocean water into "storm surges" that can drown coastal cities. Hurricanes that form over the Pacific Ocean are called typhoons.

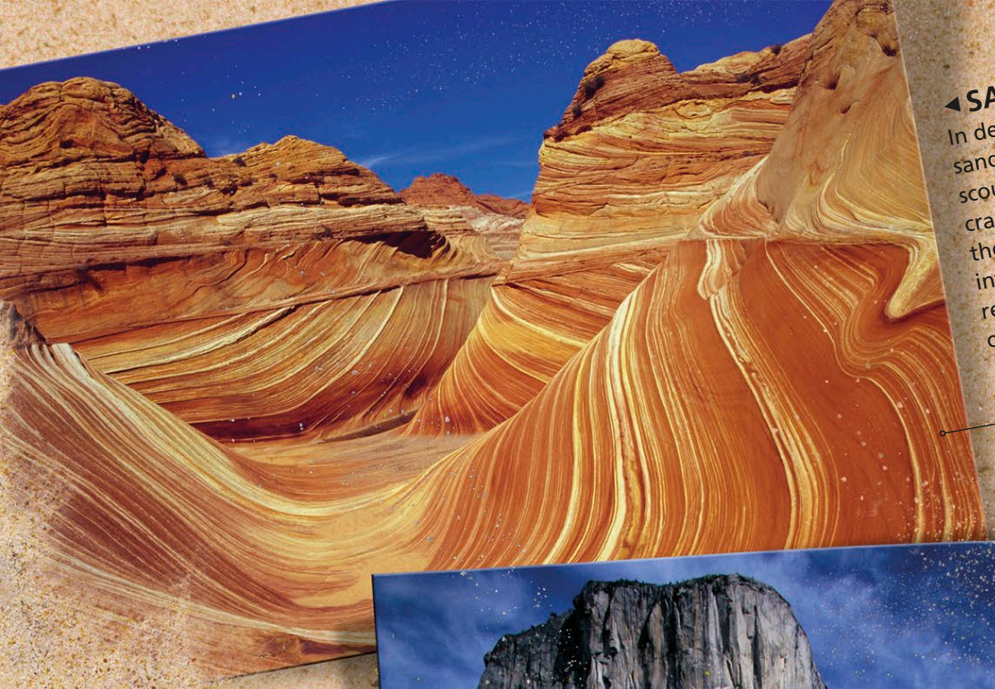
PREDICTING WEATHER ►

Satellite images like this view of a hurricane in the Gulf of Mexico can help meteorologists predict the weather. Forecasters also gather data on wind, temperature, air pressure, and other variables, and feed them into computers that are programmed with mathematical models of the atmosphere. The computers use the new data to predict how the atmosphere may react and so produce a weather forecast.



WEATHER

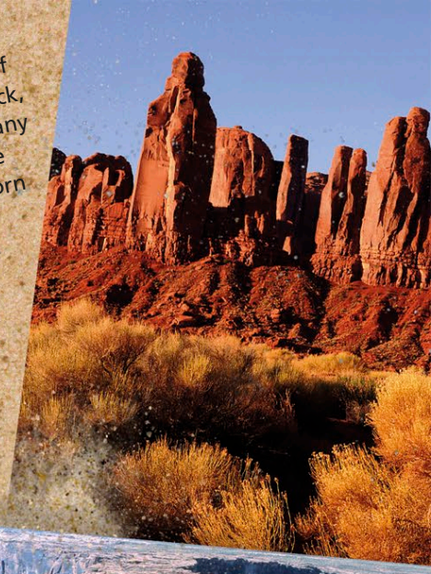
Driven by the heat of the sun, circulating currents of air swirl through the lower atmosphere, creating the winds that carry clouds, rain, and snow from the oceans over the land. Without these weather systems, the continents would be barren deserts, where life would be impossible. Sometimes, however, the weather can be so violent that it causes destruction on a terrifying scale.



◂ SANDBLASTING

In deserts, the wind picks up grains of sand and hurls them against bare rock, scouring the surface and widening any cracks. Deep beds of sandstone, like these in North America, may be worn into spectacular wavelike shapes, revealing layers of rock laid down over millions of years.

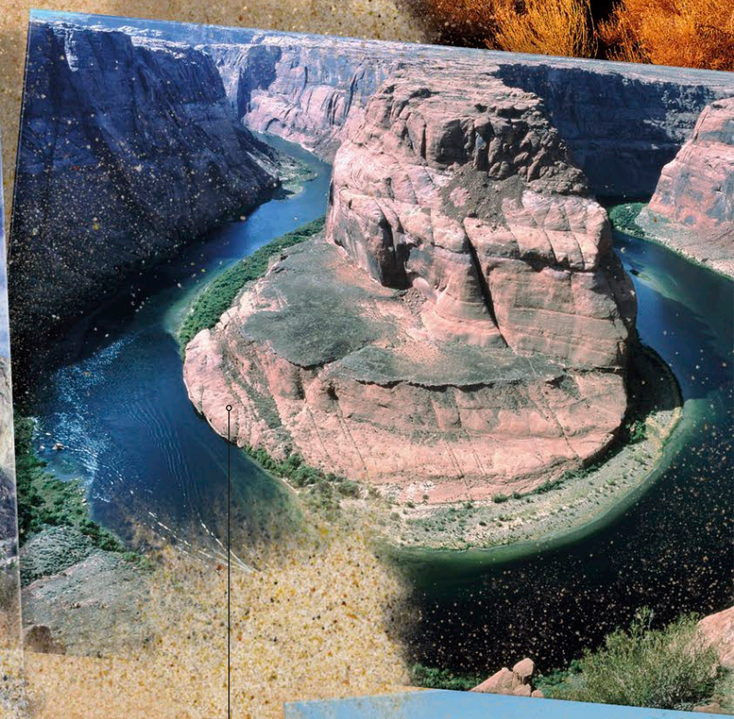
Wind erosion has turned the Coyote Buttes in Arizona into a natural work of art



The granite walls of El Capitan in California have survived millions of years of erosion

WEATHERED GRANITE ▸

Granite is an extremely hard, crystalline rock, but it can still be broken down by erosion. It is formed deep underground, and when exposed to the air, the change of pressure makes the outside layers flake away in a process called exfoliation. It can also be attacked by the acids in rainwater and scoured by ice.



Horseshoe Bend on the Colorado River formed as the river cut down through uplifted rock

Moving ice loaded with rock fragments would have once filled this Alpine valley

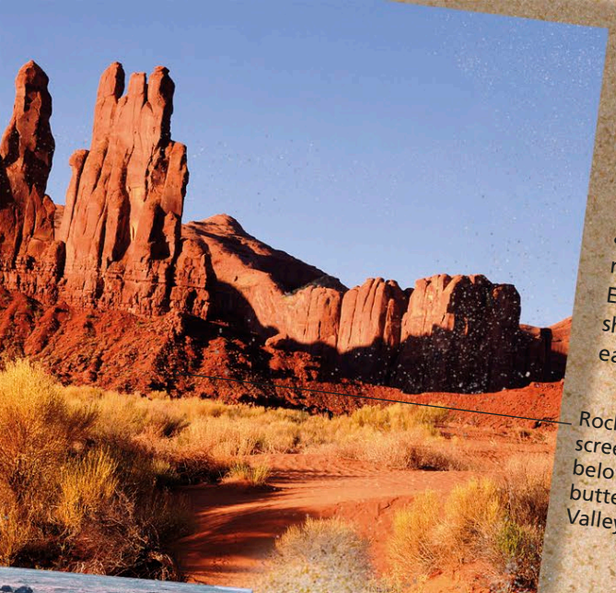
◂ CLIFFS AND STACKS

Waves crashing against coastal cliffs can cut them away at a dramatic rate. The softer rock gives way first, often leaving headlands and isolated stacks of harder rock. These stacks off the southern coast of Australia near Melbourne are known as the Twelve Apostles.

Rock is undercut by the waves so the rock above collapses, leaving a sheer cliff

EROSION

Landscapes are under constant attack from wind, rain, ice, searing heat, oceanic waves, and flowing water loaded with rock fragments. These forces gnaw away at even the hardest rocks, in the processes known as erosion and weathering. Over time, they can flatten the highest mountain ranges, carrying the rocky debris away as gravel, sand, and silt. This is deposited in the lowlands or in the sea–where, eventually, it may form new rocks.



◀ MESAS AND BUTTES

In arid terrain, occasional flash floods cut down through weak points in the rock to form valleys. These get wider and wider, carrying away the softer rock so the harder layers collapse. Eventually, all that remains are sheer-sided mesas and smaller buttes, each protected by a cap of hard rock.

Rock debris forms steep scree (rubble) slopes below the towering buttes of Monument Valley in Utah

◀ RIVER EROSION

Rivers cut V-shaped valleys and steep-sided gorges, especially where fast-flowing water carries a lot of rocky debris. The most dramatic gorges form where the land has been slowly uplifted by titanic earth movements, forcing the river to cut deeper and deeper into the landscape.

▲ VANISHED GLACIERS

In mountains, and in uplands affected by the last ice age, huge glaciers grinding along the courses of former rivers scoured them out to form deep U-shaped valleys. Where the glaciers have melted, the valleys remain, often with small rivers flowing down them.

KARST TERRAIN ▶

Rainwater is slightly acid, and this enables it to dissolve limestone. The result can be a landscape called karst, with heavily weathered bare rock riddled with caves. In tropical areas, the rock is often eroded into spectacular pinnacles.

Sharp pinnacles of limestone form the Stone Forest near Kunming, China

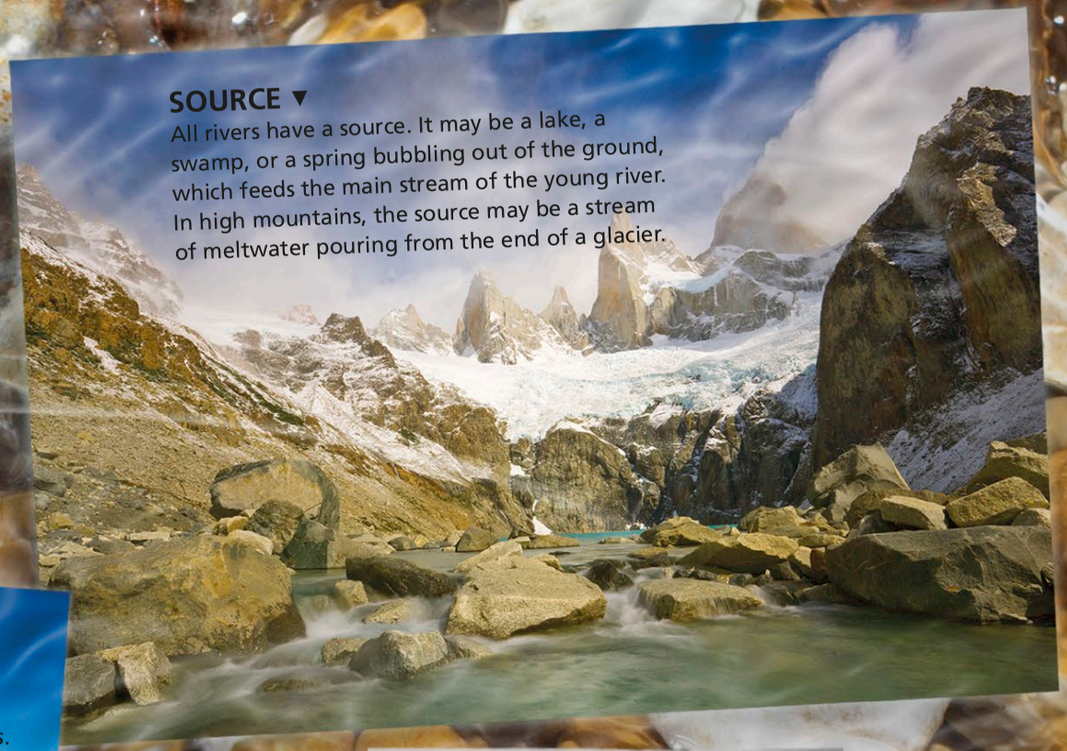
SLOT CANYON ▶

Sandy water pours off high mesas during rare but torrential desert rainstorms. It funnels through cracks in the rock at the edges of the mesas, eroding them into deep, winding slot canyons. Unlike valleys, these are often broader at the bottom than at the top.

A beam of sunlight gleams through the narrow top of Antelope Canyon, Arizona

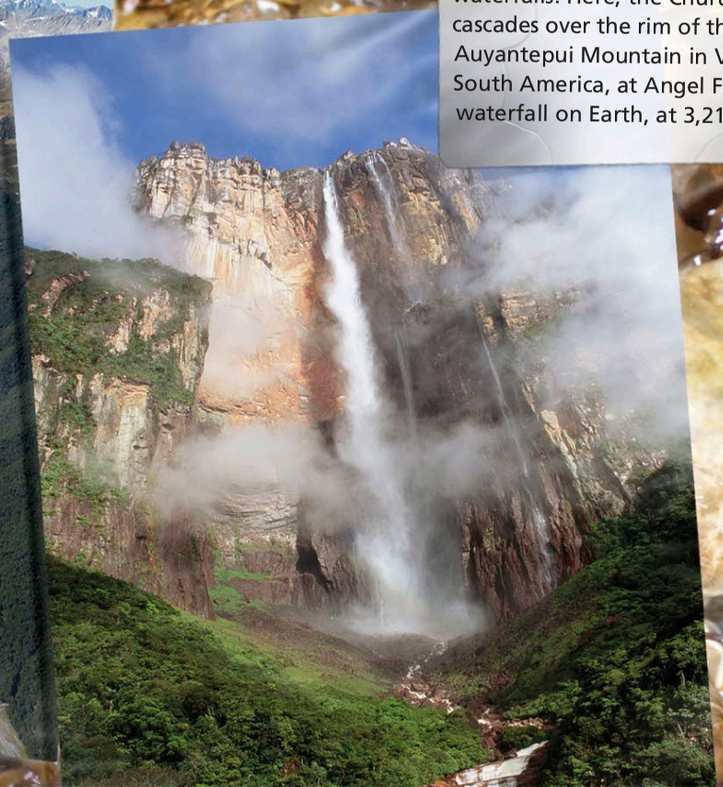
RIVERS

Most rivers flow downhill from hills or mountains to the sea. They start as fast-flowing streams, which join together to create small rivers. These often cascade down steep slopes, cutting deep valleys, until they reach flatter ground. Here, regular seasonal flooding creates broad, fertile floodplains. Each river wanders across its floodplain, growing in size but flowing more slowly, until it reaches the estuary or delta where it spills into the sea.



SOURCE ▼
All rivers have a source. It may be a lake, a swamp, or a spring bubbling out of the ground, which feeds the main stream of the young river. In high mountains, the source may be a stream of meltwater pouring from the end of a glacier.

TRIBUTARIES ▼
The main stream of a river is joined by other streams, called tributaries. They all add to the flow, especially after heavy rain and during the spring thaw when mountain snow melts. At such times, they turn into torrents, carrying masses of gravel downhill and flowing in "braided" (plaited) patterns. These braided streams flow down from Aoraki (Mount Cook), New Zealand, to join the Hopkins River.



▼ UPPER COURSE
The upland part of a river is known as its upper course. It is usually fast flowing, with a rocky bed, rapids, and even waterfalls. Here, the Churun River cascades over the rim of the flat-topped Auyantepui Mountain in Venezuela, South America, at Angel Falls—the highest waterfall on Earth, at 3,212 ft (979 m).

VALLEYS AND GORGES ▼

As a river flows down from its upper course, the water usually erodes a winding V-shaped valley through the land. Some rivers pass through steep-sided gorges, like Tiger Leaping Gorge on the Yangtze River in China. Gorges are often created by the collapse of limestone cave systems that once concealed underground rivers.

LOWER COURSE ▼

When rivers reach the lowlands, they flow more slowly but carry more water. If they are not controlled, they tend to flood each year, spilling over their banks and swamping the landscape. The floodwater leaves layers of fine silt, which build up to form a floodplain of deep, fertile soil. This makes excellent farmland. Here, the Willamette River flows across its floodplain in Oregon.

MEANDERS ▼

As it flows around a bend, river water cuts away the bank on the outside of the bend and drops sand and mud on the inside. This makes the bend more pronounced, so over time, its winding course may become a series of exaggerated loops, or meanders. Sometimes a loop is cut off to become an "ox-bow lake," seen here (center left) as the Amazon River flows through rain forest in Peru, South America.

▼ ESTUARIES AND DELTAS

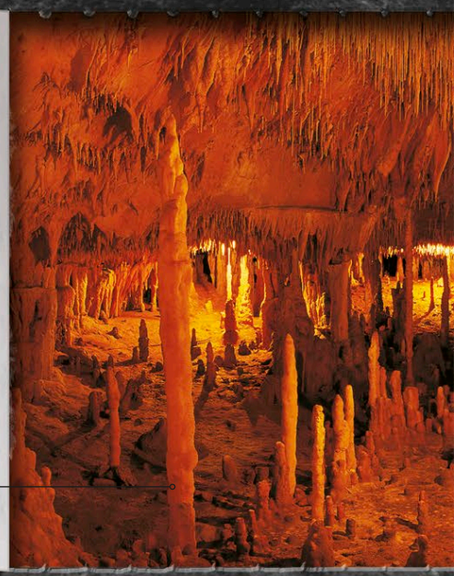
At the coast, fresh river water meets the saltwater that pushes upriver at high tide. As a result, the river drops mud particles, building up the mudflats of an estuary. If the river flow is more powerful than the flow of the tide, the flats extend out from the shore to form a wide flat area with many outlet channels, known as a delta. This view from space shows the delta of the Niger River as it meets the sea in Nigeria.

CAVES

When rock is worn away by coastal erosion or rainwater, weak areas tend to collapse while the surrounding stronger rock survives. This creates cave systems, which may extend for many miles in limestone country and contain huge caverns and underground rivers. Flowing water beneath glaciers can also erode caves in the ice. In places like Hawaii, erupting volcanoes may create lava tubes–tunnels that once contained rivers of red-hot molten rock.

LIMESTONE CAVES

Rainwater dissolves carbon dioxide from the air, turning it into weak carbonic acid. In limestone country, the acidified rainwater drains into the rock and dissolves it, creating chains of potholes and caverns. Where water containing dissolved rock drips from cave ceilings, it leaves stony deposits that build up into hanging stalactites and stalagmites that grow up from the cave floor.



This big stalagmite is made of stony calcite deposited by centuries of dripping water

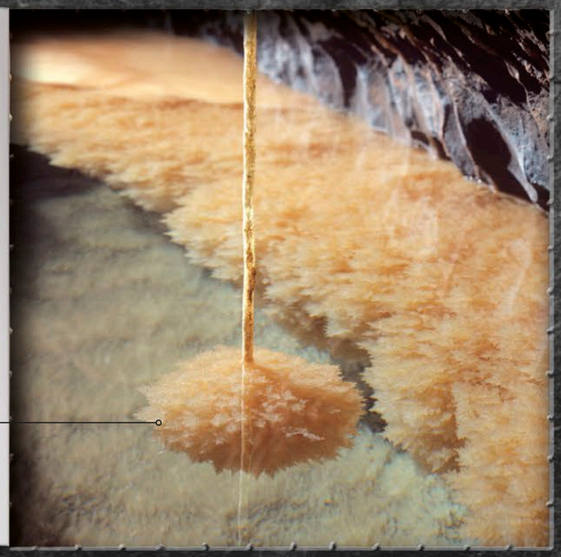
UNDERGROUND WATER

The water that creates limestone caves flows through the cave systems as underground streams and even rivers. In wet weather, these can fill the caves, eroding them into fantastic shapes that are revealed as the water level drops. In some limestone regions, such as the Yucatan in Mexico, there is no surface water at all because all the rivers flow under ground. In places they are open to the sky, they form beautiful natural wells called cenotes.

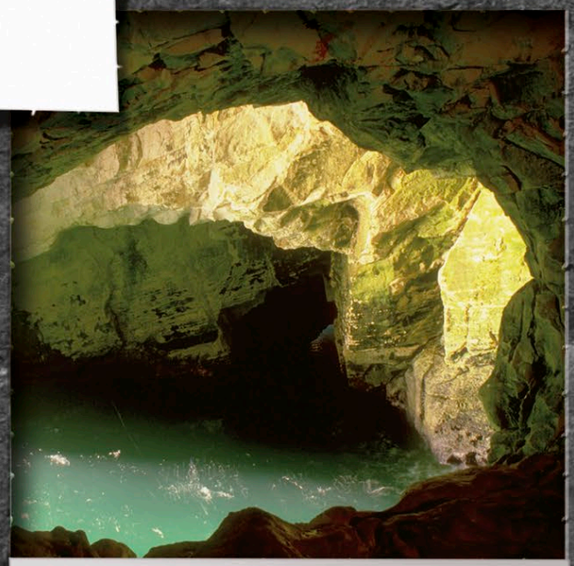
Crystal clear water reveals the banded rock structure of this cave

CRYSTALS

Water dripping through cave systems contains dissolved minerals, such as calcite and gypsum. If the water evaporates or changes its chemical nature slightly, the minerals may become solid again, forming crystals with glittering, faceted, jewel-like shapes.



Delicate calcite crystals have grown on the end of this stalactite where it enters a pool



COASTAL CAVE

On exposed rocky coasts, pounding waves force water into cracks in the rock at such high pressure that they blow the rock apart. This cuts away the rock at water level. Often the rock above collapses to form a sheer cliff, but if the waves cut into a weaker seam, they can create deep caves and even rock arches.

GLACIER CAVE

Near the end of a glacier, melting ice creates streams of meltwater that often drain down through crevasses to form vertical sinkholes. When the water reaches the bottom of the glacier, it flows between the ice and rock to erode tunnels and caves in the ancient glacier ice. At times when the melting rate is high, these can fill with water, which pours through the ice in a torrent before finally emerging at the glacier tip or snout. In midwinter, however, these glacier caves may be safe to explore.

Ice covers the floor of this glacier cave during a period of reduced melting

ICE CAVE

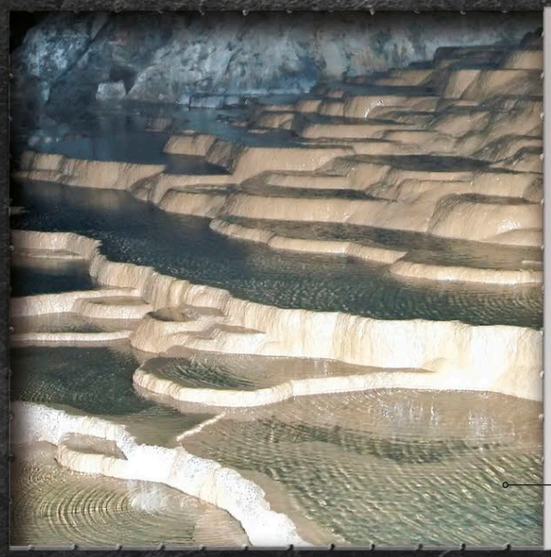
In some mountain regions, the air inside limestone caves can be so cold that water seeping into the cave immediately freezes. This creates glassy icicles and frozen cascades. The temperature is critical to the formation of these ice caves, so they are quite rare. If the rock around the cave is too cold, water freezes solid before it can enter the cave. If the cave is too warm, all the ice melts, and the water drains away through the cave floor.

Water dripping into the Grotte Casteret, in the Spanish Pyrenees mountains, forms a frozen cascade

LAVA TUBE

Now cold and empty, this cave was once filled with a torrent of red-hot lava erupting from a Hawaiian volcano. The lava from such volcanoes is so hot and liquid that it flows like water. As it pours downhill, the top of the flow cools and may become solid, forming the roof of a lava tube. This keeps the heat in and allows the lava inside to keep flowing. When the eruption stops, the lava may flow out to leave a long cave.

Solidified lava forms the roof of the lava tube



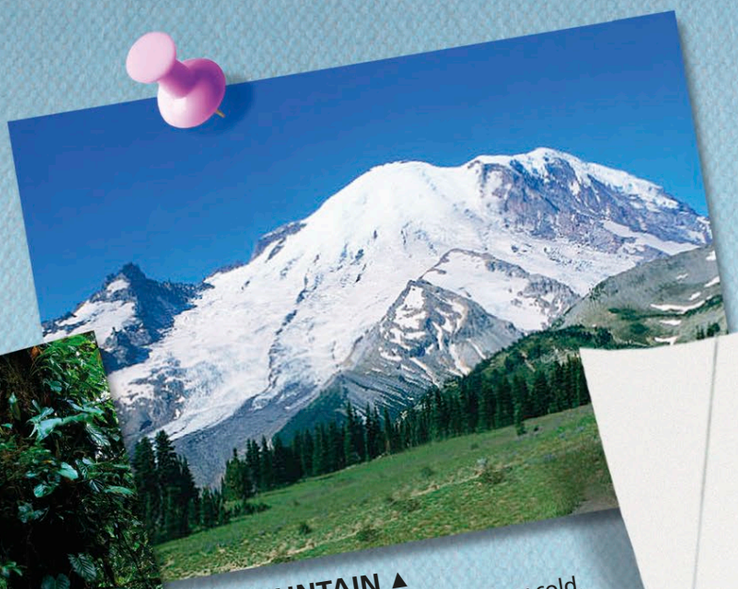
CALCITE BARRIERS

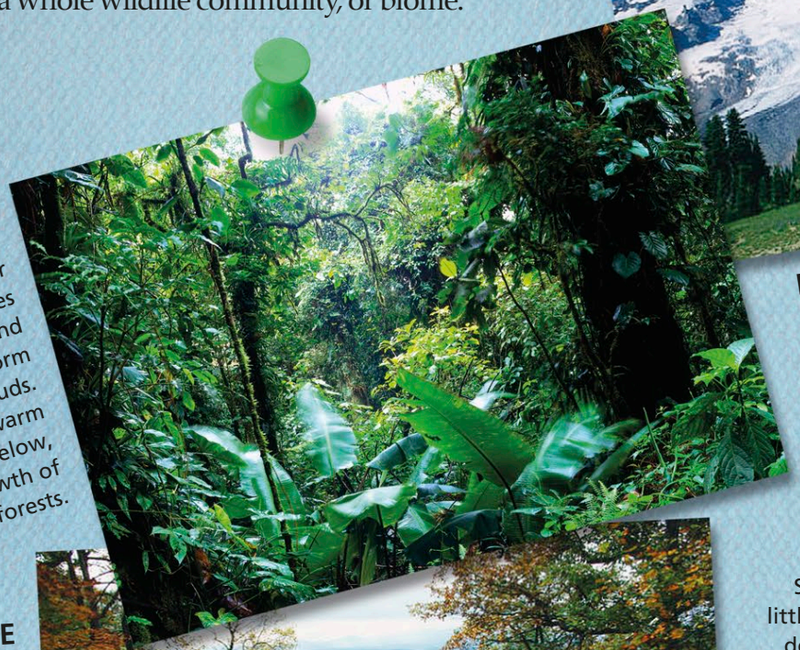
Water flowing through the limestone cave of Akiyoshi-do in Japan is saturated with dissolved calcium carbonate, or calcite. Where the water flows over the sloping cave floor, calcite has crystallized to form a series of barriers. The water overflows these in a gentle cascade that falls from one pool to the next.

Water is beautifully clear, despite being full of calcite

CLIMATE ZONES

Variations in the intensity of sunlight striking different parts of Earth drive global air movements and weather systems. Between them, these influences create a variety of climate zones, ranging from steamy tropical rain forests to the icy deserts of Antarctica. Most of these climate zones have a distinctive type of vegetation, which is the basis of a whole wildlife community, or biome.





TROPICAL RAIN FOREST ▶
Intense sunshine near the equator makes moisture evaporate and rise into the air to form huge storm clouds. These spill heavy, warm rain on the land below, fueling the growth of dense rain forests.

MOUNTAIN ▲
High mountain peaks are very cold, like Arctic tundra, and they have similar tough, low-growing vegetation. Lower mountain slopes are warmer, allowing trees to grow. The upper edge of this zone is called the tree line.

TEMPERATE FOREST ▶
Temperate climates are neither very hot nor very cold. Near oceans, the mild, damp weather allows trees to grow well in summer, but many lose their leaves and stop growing in winter.

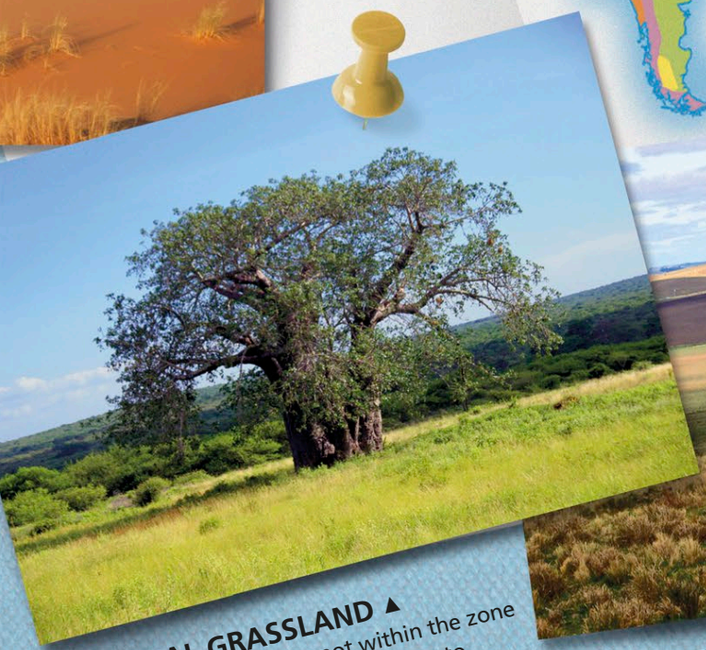
DESERT ▶
Some regions get so little rain that they are deserts. Many lie in a zone of hot, dry air near the tropics, but others are just too far from oceans. Some plants live in deserts, so they are not quite barren.

POLAR AND TUNDRA ▲
The polar regions get only weak sunlight in summer and are dark all winter. They stay frozen all year, but in the north, this icy region is surrounded by tundra, which thaws in summer allowing some plants to grow.

MEDITERRANEAN ▲
The dry shrublands that lie between the temperate zones and the main desert regions are named after the Mediterranean area where they are most common. The tough-leaved plants that live there can survive drying out in the hot summers.

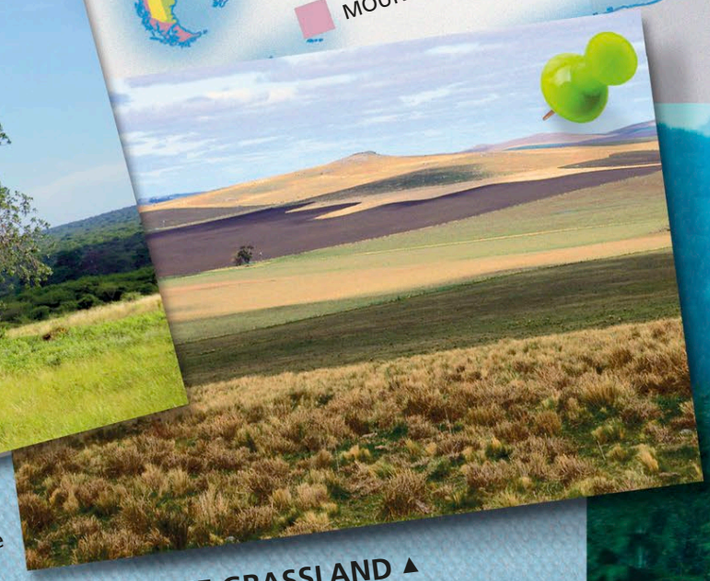
CLIMATE ZONES ▼

The climate zones of the world form bands, with tropical rain forest near the equator, most deserts in the subtropics, and boreal forest in the far north. Grasslands develop where it is too dry for trees.



TROPICAL GRASSLAND ▲

Tropical regions that are not within the zone of heavy rainfall are too hot and dry to support dense forest. They are seas of grass, often known as savannahs, sometimes dotted with trees that can withstand long droughts.



TEMPERATE GRASSLAND ▲

Some temperate areas get little rainfall, usually because they lie at the hearts of great continents. Too dry for trees, they are naturally grassy steppes and prairies—although many are now farmland.

BOREAL FOREST ▲

To the south of the Arctic tundra, the northern continents support a band of dense forest. Most of the trees are conifers with stiff needlelike leaves that can survive the long, freezing winters.

FARM CROPS

All our plant foods are grown on farms of some kind–from the huge wheat and corn fields of North America to the banana plantations and coconut groves of the tropics. The crops we harvest today are descended from plants that once grew wild but which have been bred to give high yields of juicy fruit, edible seeds, or rich vegetable oils.

Corn on the cob

Soybean pods

Dried soybeans

Soy flour

Rice seeds

Rice cakes

CORN ►

The corn grown in the Americas is actually a giant grass that grows well in sunny climates. Its big kernels can be cooked and eaten as they are or ground into flour to make tortillas and corn chips.

SOYBEANS ▲

High in protein and rich in oil, soybeans were once known only in Asia. Now popular with vegetarians, they are grown in warm climates worldwide.

RICE ▼

One of the world's three staple foods—along with corn and wheat—rice is a type of grass that grows in warm climates. It is usually cultivated in flooded "paddy" fields, which cover large areas of the tropics.

Soy sauce

Soy milk

Corn tortillas

Corn chips

Tofu is a food made from soy

Dried cocoa pod

Grains of rice

Cooked rice

Cocoa beans

Bar of chocolate

Fresh cocoa pod

◄ COCOA

The main ingredient of chocolate, cocoa beans come from the pods of the cocoa tree, grown mainly in West Africa and tropical America. The beans are first left to ferment in the sun then dried, roasted, and either ground into powder or made into cocoa butter.

POTATOES ►

The potato is the tuber (storage root) of a plant related to tomatoes. It was brought to Europe from South America in the 16th century, and since then, it has become one of the world's main foods.

White potatoes

Red potatoes

WHEAT ▼

Wheat is the most important grain crop in mild northern climates, where it is cultivated on a vast scale. A member of the grass family, wheat has been bred to have large seeds for grinding into flour.

Fresh tea leaves

Tea bags

◄ TEA

The leaves used to make tea come from an evergreen bush that grows in tropical and subtropical climates. It is cultivated mainly in China and India, where the leaves are handpicked and quickly dried. Leaf tea can be used as it is or in paper tea bags.

Bread made from wheat flour

Vine of red tomatoes

TOMATOES ▲

Closely related to potatoes, and introduced from the same region of South America in the late 1500s, the tomato is now grown almost worldwide.

Inside a yellow tomato

Bunch of wheat seedheads

Dried tea leaves

GRAPES ▲

One of the oldest cultivated plants, the grape was grown by Ancient Egyptians 6,000 years ago. Planted in permanent vineyards in warm climates, grapes are harvested for winemaking, eating fresh, and drying as raisins, sultanas, and currants.

SUNFLOWERS ►

The spectacular blooms of sunflowers are made up of hundreds of big seeds. These can be eaten as snacks, but most are processed to produce oil, which is used in cooking. Bees love sunflowers and turn the nectar into honey.

◄ SUGAR CANE

Grown on plantations in tropical and subtropical regions of the world, sugar cane is the thick stalk of a large grass. More than half the world's sugar comes from sugar cane. It is also made into alcohol used in biofuels (fuels made from renewable organic material, such as plants).

◄ BANANAS

Bananas grow in bunches of up to 200, sprouting from clusters of huge leaves that shoot up from fleshy roots. They are a valuable crop throughout the tropics and are usually cut while green so they are perfectly yellow and ripe when sold.

COFFEE ▼

Coffee is one of the most valuable crops produced in the tropics. It is made from the seeds of a small tree. Each red berry contains two seeds, or beans, which are dried in the sun before being roasted and ground.

COCONUTS ►

The big nuts of the coconut palm are an important crop on many Pacific islands. The fibrous husk is used for matting and rope making. The white "meat" of the nuts is used for food, either fresh, desiccated (dried), as creamed coconut, or as coconut oil.

ENVIRONMENT

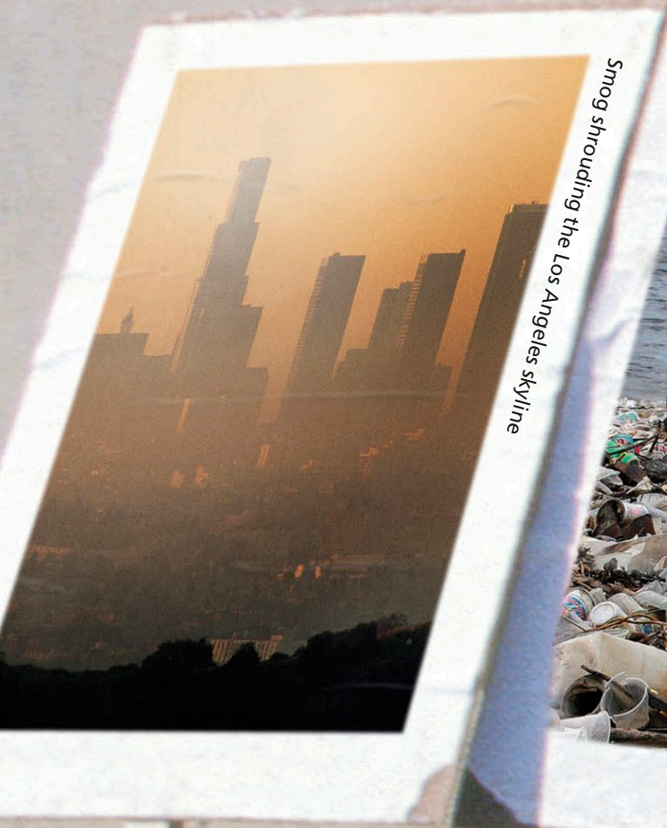
As the human population grows and we exploit more of the world's resources, we inflict a lot of damage on our environment. We are doing this partly by destruction of natural habitats, such as forests and wetlands, and partly by pollution of the land, oceans, and atmosphere. Many plants and animals are endangered, and entire ecosystems such as coral reefs and rain forests are under threat.

▼ LAND AND SEA POLLUTION

A lot of the things that we throw away end up scattered over the landscape, or dumped in the sea. Most plastic never rots down and is dangerous to wildlife. Raw sewage and other waste is also poisoning enclosed seas such as the Mediterranean.

▼ GLOBAL WARMING

The most serious threat to the environment is global warming. This is caused by pollution of the air by gases that absorb heat and warm up the atmosphere. This may lead to changes in rainfall patterns and rises in sea levels as polar ice caps melt.



Smog shrouding the Los Angeles skyline

Garbage in Guanabara Bay, Brazil

▲ AIR POLLUTION

Smoke and gases released by industry, power stations, homes, and vehicles have caused visible air pollution, known as "smog," in many cities. Badly polluted air can be dangerous to breathe, but the main threat from this kind of pollution is global warming.

Plastic waste floating in the sea can trap and kill marine animals and pollute beaches

Coral reefs are dying as oceans become warmer, and many types of coral may soon be extinct

▼ ACID RAIN

Smoke and fumes from industry and power stations combine with moisture in the air to form weak sulfuric and nitric acids. When this acid rain falls it can kill trees and turn lakes too acidic to support life. This is a serious problem in Canada, Russia, and China.

The worst effects of acid rain are suffered in areas that are close to industrial regions

Forest destroyed by acid rain near the Appalachian Mountains

▼ DEFORESTATION

All over the world, vast areas of forest are being destroyed each year. Tropical forests in particular are being felled for lumber and to clear land for farming. This is wrecking some of the richest natural habitats on Earth and is one of the main causes of climate change.

Rain forest clearance in Chiapas, Mexico

Coral reef, Fiji

Giant panda in Wolong Nature Reserve, Chengdu, China

◄ LOSS OF BIODIVERSITY

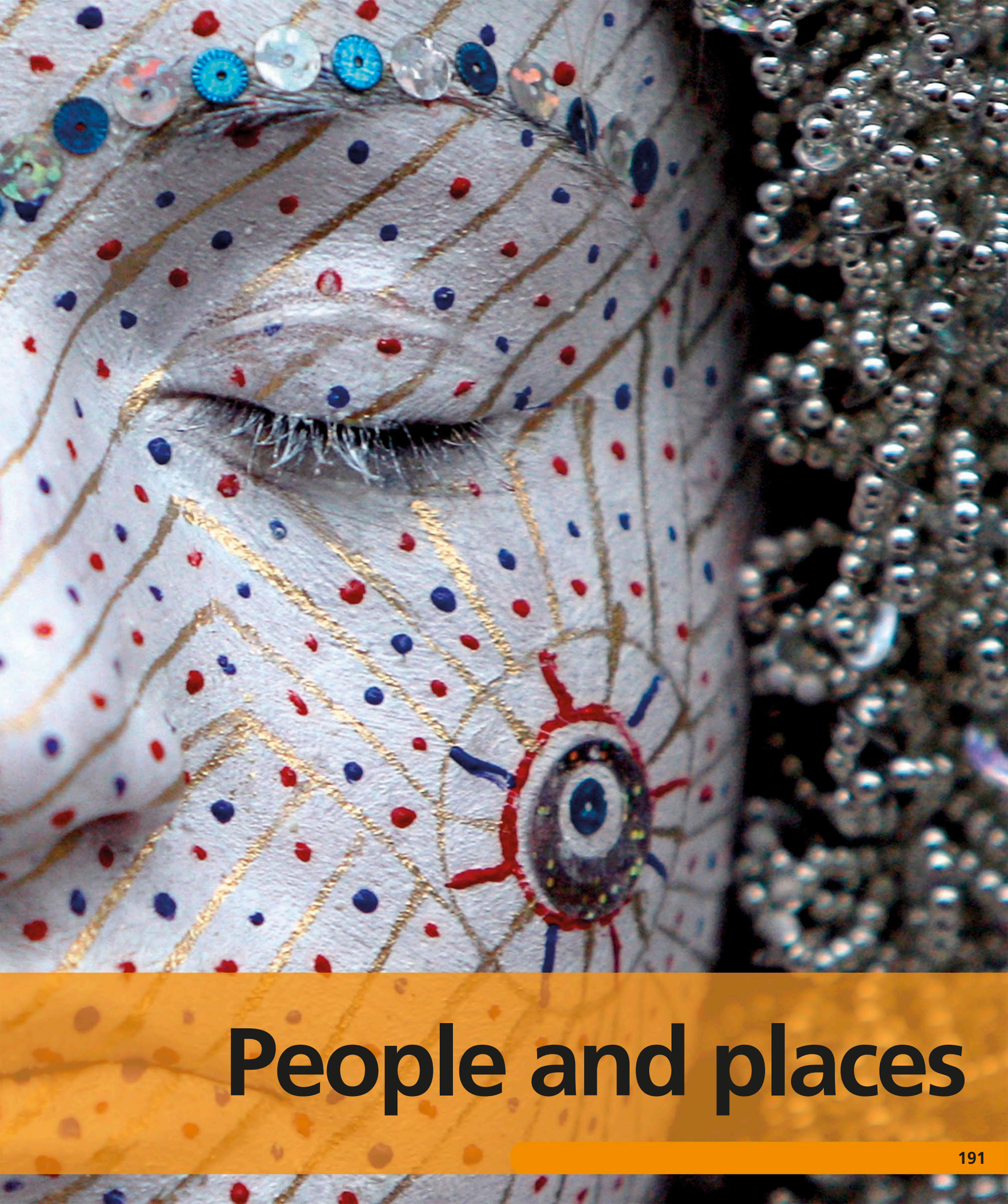
As wild habitats are destroyed, plants and animals have fewer places to live. This makes survival harder for many species. As endangered species die out, it reduces the rich variety of life that is vital to the health of the planet.

Cycling to work in San Francisco

PROTECTING EARTH ►

Protecting the environment is not just the job of governments. We can all help by altering the way we live. By cycling to work instead of driving, these city workers are reducing the amount of pollution they produce.

PAINTED BRIDE
At a traditional wedding in the Balkan village of Donje Ljubinje, the bride's face is painted to ward off bad luck. The custom is unique, as is the villagers' language—a mixture of Serbian, Macedonian, and Turkish.



People and places

Injera is an African flat bread, served here with beef stew and veggies

Moroccan spices

One-third of the world's gold is produced in Johannesburg

FOOD
Africa's staple foods are crops such as corn, yams, cassava, and plantains. Fish and meat are rarely eaten as a main dish but are added to other ingredients, including beans and lentils. In towns all over Morocco and Tunisia, people sell their homegrown produce at local markets.

INDUSTRY
Nigeria, Algeria, and Libya are major sources of oil and natural gas, while gold and diamonds have made South Africa prosperous. Minerals are mined in the Congo and Zambia, and copper and tin are exported from Namibia.

Nigeria is one of the world's main oil producers

AFRICA

The discovery of fossilized remains in Africa has led experts to agree that the world's first humans originated from this continent millions of years ago. Today, the population stands at about 1.3 billion, with many people living in rural regions of the 54 countries. Africa's diversity is seen in its varied cultures, long-standing customs, striking scenery, and wildlife. This captivating mix attracts a steady stream of visitors.

Drum

MUSIC
Celebrations in Africa are usually accompanied by music, with percussion instruments the most popular. Many types of drums are used to create traditional beats, with animal horns and shells blown to make different sounds. Stringed instruments, such as the kora, and double bells, such as the kuge, are also played.

The Masai "jump-dance" to music, as a show of strength

Kora

Kuge

Sahara Desert

Stunning views over Cape Town and Table Mountain in South Africa

Mount Kilimanjaro lies on the Tanzania/Kenya border and rises 19,340 ft (5,895 m)

The Sphinx, and Great Pyramids attract tourists to Egypt all year round

TOURISM

Visitors to Africa go on safari to see the wildlife at close range. The economy is also boosted by tourists soaking up the sun on the beaches of Tunisia, Morocco, and South Africa, as well as the islands of the Seychelles. One of Africa's most visited historic sites is the ancient pyramids of Giza in Egypt, built some 4,500 years ago.

LANDSCAPE

North Africa boasts the world's largest desert, the Sahara, where temperatures can top 122°F (50°C). Africa's center is mainly rain forest and rivers, a contrast to the grassy plains down south. Natural landmarks include Kilimanjaro (Africa's highest mountain), the Nile (the longest river), and Lake Victoria (the largest lake).

Endangered mountain gorillas live in Rwanda's Volcanoes National Park

Dates

Head of corn

FARMING

Many Africans in rural villages grow root vegetables and corn to sell at markets. Northern Africa has the best climate for cultivating dates, olives, and citrus fruits. Kenya's rainfall yields high tea production, while the Ivory Coast and Ghana put together produce more than half the world's cocoa. Cotton is grown for export.

Fibers from the cotton boll plant are used to weave cloth

Cocoa pod

WILDLIFE

Game reserves in Kenya and Tanzania have been established to protect Africa's wildlife. Today, zebras, giraffes, elephants, and big cats roam freely without fear of human hunters. The continent's largest island is also rich with wildlife. Three-quarters of Madagascar's animals are found nowhere else.

Ring-tailed lemurs are native to the island of Madagascar

Zebra

Judo

The stock exchange in Tokyo is the third largest in the world

Freshwater crocodile

SPORTS

There is a long tradition of martial arts in Asia, which includes judo, karate, and sumo wrestling in Japan and kung fu in China. Mongolians and Tibetans were once expert horseback riders, and racing remains a common pursuit. India, Pakistan, and Sri Lanka excel at cricket, while table tennis is also popular.

INDUSTRY

By exporting resources of oil and natural gas, Asian nations such as Saudi Arabia, Iraq, and Kuwait have become wealthy. Japan, too, has seen rapid economic growth from its cutting-edge technology. India, China, and other Asian countries have benefitted from mass-producing cars, clothes, and electronics for export.

WILDLIFE

Some of the world's most endangered mammals are found in Asia, including the snow leopard, red panda, and Asiatic black bear. The forests of Malaysia, Indonesia, and Borneo shelter elephants, tigers, and orangutans from the heat. Sharks, turtles, and manta rays live among the reefs off the coast of southeast Asia.

Table tennis, along with soccer, is China's most popular sport

Rice is Asia's staple food and has been cultivated for more than 9,500 years

South Korea is the fifth-largest car-manufacturing nation in the world

The *Sasakia charonda* butterfly, nicknamed Japanese emperor, is Japan's national butterfly

Tiger

ASIA

The largest continent is a land of extremes. From the ice of the Arctic to the heat of the Indian Ocean islands, Asia takes in treacherous mountains, desolate dunes, treeless steppes, fertile plains, and tropical rain forests. The continent's 48 countries show many contrasts, with businesses booming in the expanding cities, while rural communities farm the fields. Today, more than 60 percent of the world's population call Asia their home.

FOOD

Asia's dishes are derived from the rich mix of cultures. Culinary delights from India (unique blends of spices for curries), China (fried rice, meat, and vegetables), Thailand (curries with coconut milk and rice or noodles), and Japan (raw or cooked fish dishes called sushi) have made Asian cuisine a hit with locals and tourists alike.

China grows the most tea in the world, followed by India. In India, the plants are grown in the cooler hill regions of the north

Pho Bac, beef noodle soup

Sushi

CULTURE

India's successful "Bollywood" film industry produces more than 1,000 films a year from its base in Mumbai. Art, music, and dance are also deep-rooted in Asian culture, with Bhutan's masked temple dancers, Cambodia's classical dances, and Indonesia's shadow puppets.

"Bollywood" films take their name from of the "B" of Bombay, now called Mumbai

Dragon masks make a colorful sight at dragon boat festivals and Chinese New Year

At the Western Wall in Jerusalem, Jewish people gather to offer prayers

Golden Buddha

RELIGION

All the main religions started in Asia. Although religions differ from country to country, the three faiths most followed today are Buddhism, Hinduism, and Islam. People worship by chanting or praying, at home, in temples, or in mosques. Buddhism and Hinduism focus on spiritual enlightenment.

Bathing on the banks of the Ganges River at Varanasi is a holy act for Hindus

Petronas Towers in Kuala Lumpur, Malaysia

CITIES

The economic boom in Asia has produced supercities. Dubai, Kuala Lumpur, and Hong Kong are now centers of finance, culture, and tourism, where ancient temples sit next to high-rise offices. Many people leave rural areas for cities, resulting in a combination of slums and luxury living.

A traffic jam in Delhi, India's second largest city

The bright lights of Hong Kong, home to 7.4 million people

FOOD

The US is famous for its fast food, especially hamburgers, hot dogs, and soft drinks. These foods can be prepared and served quickly. A wealth of fresh fruit and vegetables grown in California and Florida provide a healthy option. Down Mexico way, the preference is for spicy foods with chilies.

Hamburger

Most of the peanuts grown in the US are made into peanut butter

CULTURE

American movies and TV shows are popular around the world. Many famous music styles, such as rock and roll, jazz, blues, country, and soul, have their roots in the US. Canada's annual Calgary Stampede celebrates its cattle-trading roots, while Mexico has parades and feasts on saints' days.

Elvis Presley became the ultimate icon of US rock-and-roll music

Canada's maple trees produce 71 percent of all maple syrup worldwide—a favorite on pancakes

The US grows 10 percent of the world's oranges

Baseball glove and ball

SPORTS

The highlight of the American football calendar is a championship game called the Super Bowl. This is the most watched television event in the US. Baseball and basketball are also long-standing favorites. The colder climate of Canada has made skiing, ice skating, and ice hockey the main winter pursuits.

Statue of Liberty

LANDMARKS

New York's Statue of Liberty welcomed immigrants arriving by boat, while the One World Trade Center is the city's tallest building. Another US landmark is Mount Rushmore, where the faces of four US presidents are carved into the rock. Far older landmarks can be found in Central America with the ruins of Aztec and Mayan civilizations.

Mount Rushmore

Ice hockey skate has blade to enable hockey player to glide across the ice

Mexico's guitar groups play and sing their traditional mariachi music

Oscars are statues given to movie industry winners at Hollywood's Academy Awards

The Rocky Mountains stretch from Alaska in the north to the US border in the south

The Grand Canyon was formed by water and ice over millions of years

LANDSCAPE

One-third of Canada lies inside the Arctic Circle and stays frozen most of the year. Heading down through North America's snowy Rocky Mountains and forested Appalachians, the scenery turns into grassy plains, known as prairies. The US is a mix of plains, deserts, and national parks such as Yellowstone and Yosemite. Farther south are the beaches of Mexico and the Caribbean.

NORTH AMERICA

Before the arrival of Europeans in the 16th century, tribes of native peoples were the only inhabitants of North America. Since then, waves of immigration to both Canada and the US have made these countries pioneers of financial growth and contemporary culture. The mainly Spanish-speaking countries of Central America have lush, mountainous landscapes and are rich in tradition and culture.

American football helmet

Bison

Gray-banded kingsnake

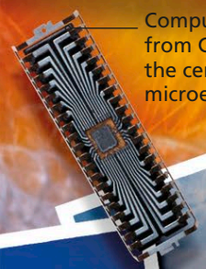
Canada's harp seal pups are born with fluffy white fur for extra warmth

WILDLIFE

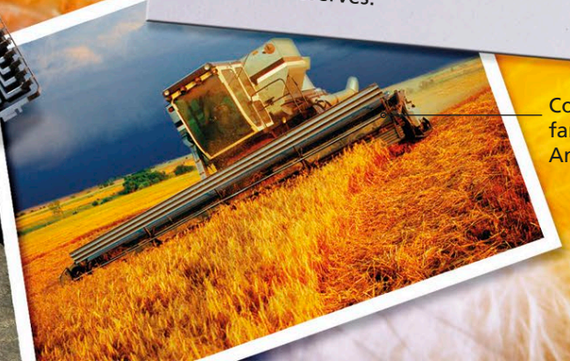
Northern parts of Canada host more animals than people, including bears, elk, and moose in the Rocky Mountains. Across the US, national parks protect bison, antelope, and deer. Florida's Everglades is a unique wetland area, with many rare animals such as the Florida panther and manatee. Snakes and scorpions can survive the heat of Mexico's Sonoran Desert.

INDUSTRY

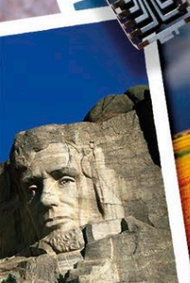
The US grew wealthy by producing vast quantities of wheat, iron, steel, electronics, cars, and aircraft. Fishing is an important industry along the Pacific Coast, with salmon canned for export. Canada is the largest exporter of forest products, mainly softwood used in construction, while Mexico sells its natural gas and oil reserves.



Computer chips from California, the center for microelectronics



Combine harvesters farm wheat on the American prairies



Cadillac car

PHYSICAL FEATURES

Three contrasting landscapes dominate South America. From the west rise the towering peaks of the Andes Mountains, leading down to the Pacific Ocean. In the northeast is the dense Amazon rain forest, which spreads across half of Brazil. To the south are vast, grassy plains called the pampas (which means "flat" in Spanish).

The Patagonia region at the southern tip of the continent is known for its dramatic glaciers

Angel Falls in Venezuela drops 3,212 ft (979 m) and is the highest uninterrupted waterfall in the world

In the rainy season, the Amazon River floods, covering large parts of the rain forest in water

CULTURE

Music and dance form the heart of South American culture. The rhythmic dance of the samba is a notable highlight of Rio de Janeiro's famous five-day carnival, which features spectacular parades and parties in Brazil's capital. Another common sight is soccer games on the streets and beaches.

The tango dance evolved in Argentina's slums during the late 19th century

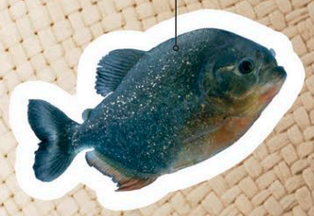
In 2002, Brazil won soccer's World Cup for a record-breaking fifth time

WILDLIFE

The Amazon is the world's largest rain forest and could contain 10 percent of all animal species. Jaguars, sloths, and tapirs live under the tree canopy, while the forest floor teems with snakes, lizards, and insects. Colorful toucans, macaws, and kingfishers swoop over the Amazon River, where dolphins and turtles swim.

The toucan's large beak enables it to pick fruit from trees

Red-eyed tree frogs are active at night, searching for insects to eat



Sharp-teethed, meat-eating piranhas swim in South American rivers

Brazil nuts

CROPS

Brazil produces one-third of the world's coffee, while Ecuador's climate is ideal for growing tomatoes and bananas. Steep hillsides are terraced for farming in Chile and Peru, where potatoes are planted on the higher slopes of the Andes, and corn is sown lower down.

Coffee beans

Banana

Sap is collected from rubber trees in the Amazon rain forest to produce rubber

SOUTH AMERICA

Rich in history, language, and culture, South America is a vibrant place. Nature has made its mark in the trees of the Amazon rain forest, while ancient civilizations have left theirs in the city of Machu Picchu in the Andes Mountains. The influence of Spanish and Portugese colonization remains in the languages, while samba sounds and traditional tangos resonate at the festivals.

Hippeastrum is a colorful plant that thrives in Peru and Chile and produces flowers up to 10 in (25 cm) across

Cardon cactus

This ear ornament was made by the Chimu, a people who were eventuallly conquered by the Incas

Peruvian dolls were handmade from llama or alpaca wool

Yerba mate leaves are used to make a popular tea, drunk from a hollow gourd (shell)

Beef is a key component of Argentine cuisine

TREES AND PLANTS

A large part of the continent is pampas (grassy plain), which is one of the richest grazing areas in the world. Variety comes from the Amazon rain forest, where about 40,000 species of plants flourish. Unique plants grow in Venezuela's sandstone hills and Chile's Atacama Desert, where species have adapted to survive the lack of water.

INCAS

The Incas were the last great civilization to emerge in South America. During the 12th century, expert architects created their capital at Cusco. By the 15th century, their empire had spread from Equador through Peru to Chile. Hearing of great riches, the Spanish arrived in 1532 to set up colonies and ended the Inca reign.

FOOD

Corn is a staple food used in bread and cakes stuffed with meat or cheese. Potatoes, squash, rice, and different types of beans are also mealtime favorites. Peruvians love spicy foods, so hot chili peppers are often on the menu.

Roger Federer celebrates winning a Wimbledon title at the famous tennis competition in London

The Tour de France was first held in 1903 and is now the world's biggest cycling race

This famous clock tower is part of Britain's Houses of Parliament

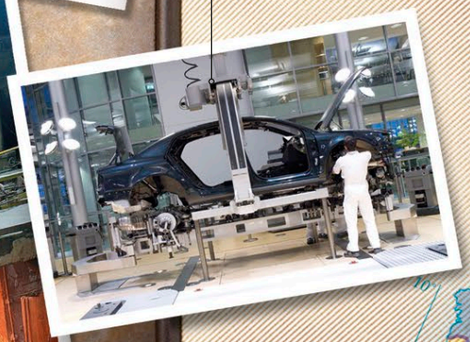
SPORTS

The British, Spanish, and Italian soccer leagues are considered the best in the world. Soccer and rugby are played throughout the year, tennis and cricket are summer sports, and mountain ski resorts have busy winter seasons.

Formula 1 car racing is a popular sport in Europe

Portugal has some of the best deep-sea fishing in Europe

The steel industry is thriving in eastern Europe



Germany is one of the world's leading car producers

Flower farming, especially tulips, is an important industry in Holland

INDUSTRY

Germany is the continent's industrial leader, with its car production and high-tech goods industries. Forestry flourishes in Finland and Sweden, while cod fishing is big business in Norway and Iceland.

About 60 percent of farmland in Greece is used to grow olives

ICELAND
NORWAY
SWEDEN
FINLAND
Gulf of Bothnia
Shetland Islands
Orkney Islands
Outer Hebrides
Scotland
Northern Ireland
IRELAND
UNITED KINGDOM
Wales
England
North Sea
DENMARK
ESTONIA
LATVIA
LITHUANIA
RUSSIA (Kaliningrad)
Baltic Sea
BELARUS
NETHERLANDS
English Channel
BELGIUM
GERMANY
POLAND
LUXEMBOURG
CZECH REPUBLIC (CZECHIA)
SLOVAKIA
Bay of Biscay
FRANCE
LIECHTENSTEIN
SWITZERLAND
AUSTRIA
HUNGARY
MOLDOVA
SLOVENIA
CROATIA
ROMANIA
PORTUGAL
MONACO
ANDORRA
SAN MARINO
Adriatic Sea
BOSNIA & HERZEGOVINA
SERBIA
SPAIN
Corsica
ITALY
MONTENEGRO
KOSOVO (disputed)
BULGARIA
Mallorca
Menorca
Ibiza
Balearic Islands
Sardinia
Tyrrhenian Sea
ALBANIA
MACEDONIA
TURKEY
Gibraltar (to UK)
Mediterranean Sea
Aegean Sea
GREECE
Sicily
Ionian Sea
MALTA

EUROPE

For a small continent, Europe has a made a big impact. In centuries past, its inhabitants spread across the globe, building empires. Those days are gone, but the continent's influence remains clear in the European languages, architecture, and entertainment still evident around the world. Thanks to industrial growth and big business, many of the 44 countries are wealthy, with people enjoying a high standard of living.

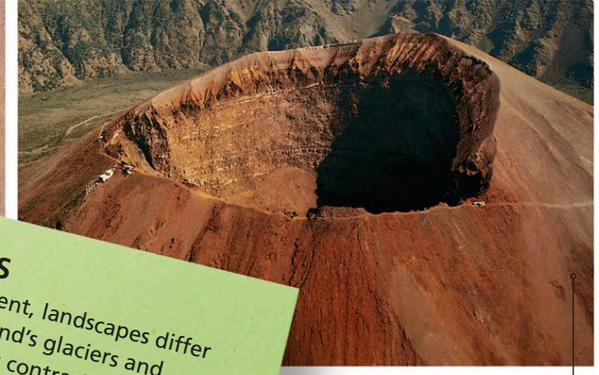
CITIES

Many European cities feature castles and cathedrals. The center of the eastern European city of Prague is a World Heritage Site. Paris and Milan are fashion leaders, while the financial centers of London and Geneva are among the world's richest cities.

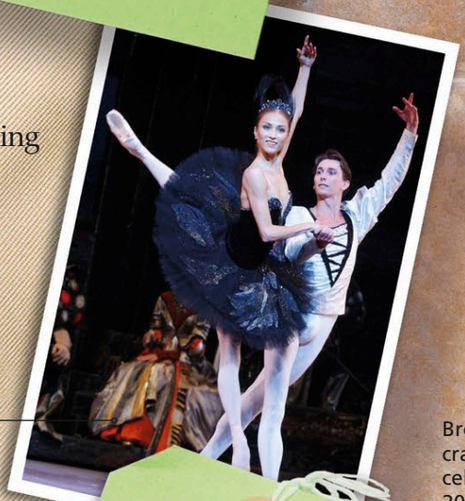
Norway's spectacular fjords are one of Europe's most photographed landscapes

LANDSCAPES

Across the continent, landscapes differ dramatically. Iceland's glaciers and Norway's fjords contrast with the mountain ranges of the Alps and Pyrenees. Around the Mediterranean are fertile fields and sandy beaches.



The active volcano of Mount Vesuvius in Italy stands 4,200 ft (1,280 m) tall

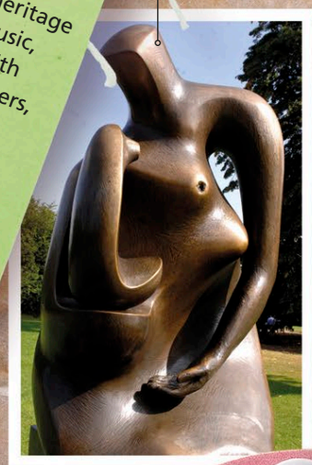


Russia is famous for its ballet companies, such as the Bolshoi Ballet of Moscow and the Kirov Ballet of St. Petersburg

CULTURE

Europe has a rich heritage of literature, art, music, opera, and ballet, with many pioneering writers, artists, composers, and dancers capturing the public imagination. Museums, theaters, opera houses, and art exhibitions draw crowds in the major cities.

Painted in 1888, *Sunflowers* by the Dutch painter Vincent Van Gogh is one of the world's best-known works of art

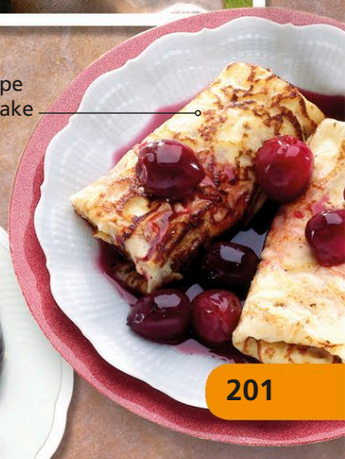


Bronze statue crafted by celebrated 20th-century British sculptor Henry Moore

Paella is a rice-based dish containing meat and seafood

FOOD

Pizza and pasta are Italian favorites, while France is synonymous with strong cheese, crêpes, and mussels. Germans serve smoked sausages, Spaniards prepare their specialty paella, and sweet-toothed Belgians are known for their luxurious chocolates.



Crêpe is a type of thin pancake

Mussels are a popular dish in Belgium and France

CULTURE

The beliefs, culture, and art of the continent's original inhabitants form a rich heritage. Aboriginal Australians have a deep-rooted respect for the natural world. The Maoris of New Zealand practice a traditional dance called the *haka*. The Polynesians of the Pacific Islands enjoy a family-centered culture.

Aboriginal art depicts patterns or scenes from the natural world

Religious and mythical symbols were carved into the wood of Polynesian dolls

Maori tools were blessed by their creators to ensure they worked well

SPORTS

The climate allows Australasians to make the most of the great outdoors. Cricket, rugby, and golf are popular pastimes, while sailing and surfing are coastal favorites. Preferred spectator sports are tennis, cricket, and rugby, with Australia's cricket side and New Zealand's rugby union team enjoying huge success.

Funnel-web spiders live in eastern Australia and can kill a person with a single venomous bite

WILDLIFE

Australasia's best-known native creatures are marsupials (mammals that hold their young in a pouch), such as kangaroos, koalas, and wombats. Many birds are also unique to the continent, including kookaburras and emus. Some of the world's deadliest snakes and spiders live there as well.

Koala

Kangaroo

Australia's thorny devil is a spiny lizard that blends in with its desert surroundings

The trunk of the baobab tree stores water to survive periods of drought

TREES AND PLANTS

Australasia has many trees and plants that don't grow anywhere else. About 80 percent of New Zealand's plants are unique, while nearly all the world's eucalyptus trees originated in Australia. The country's center is hot and barren, but trees, plants, and fungi thrive in the humid rain forests.

Gabiny fruit

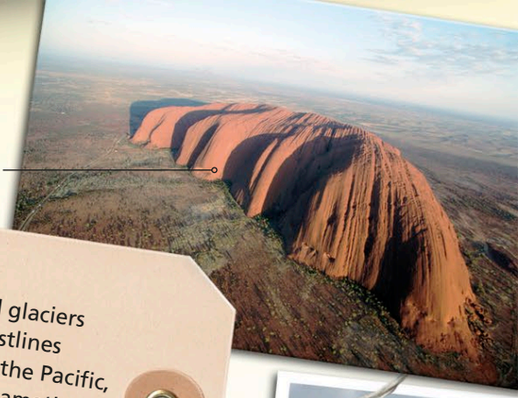
Eucalyptus leaves provide the main source of food for koalas

INDUSTRY

Sheep and cattle farming has made lush New Zealand a major exporter of wool, meat, and dairy products. Rich in natural resources such as iron ore, gold, nickel, silver, and diamonds, Australia is the leading exporter of coal. Minerals such as copper and gold are Papua New Guinea's main exports.

Australia's cricket team

New Zealand's All Blacks rugby team

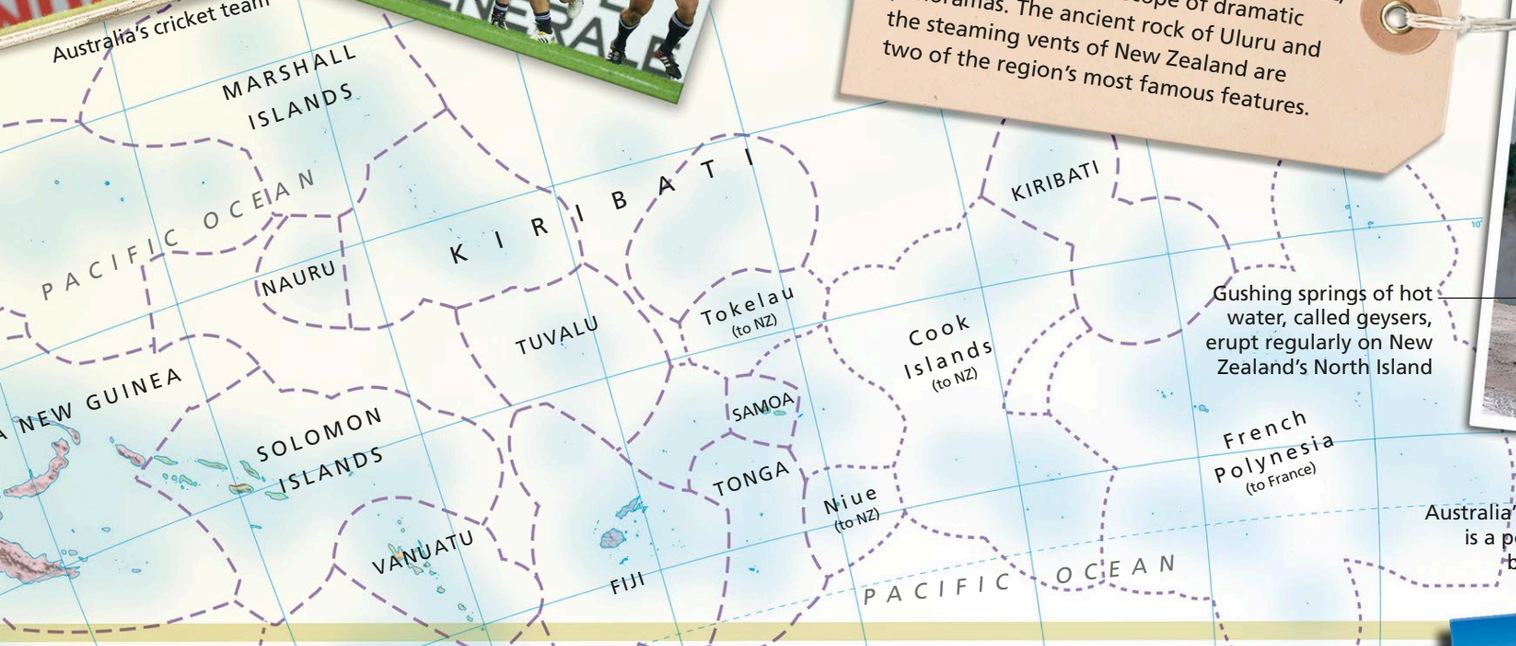


The huge sandstone rock of Uluru is an ancient site sacred to Aboriginal people

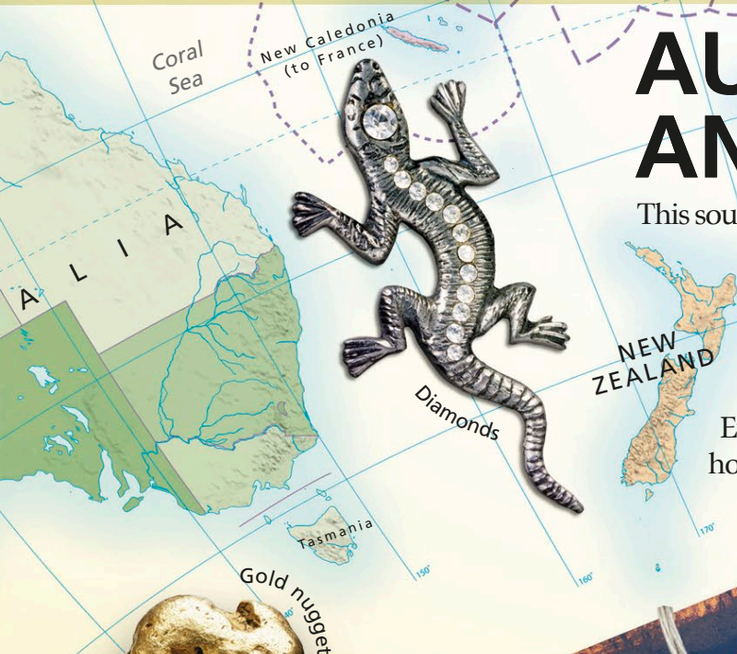
PHYSICAL FEATURES

From New Zealand's geysers and glaciers to Australia's coral reefs and coastlines and the many volcanic islands of the Pacific, the region is a kaleidoscope of dramatic panoramas. The ancient rock of Uluru and the steaming vents of New Zealand are two of the region's most famous features.

Gushing springs of hot water, called geysers, erupt regularly on New Zealand's North Island



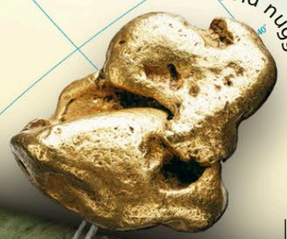
Australia's Sunshine Coast is a popular stretch of beaches and bays



AUSTRALASIA AND OCEANIA

This southern-hemisphere region includes Australia, New Zealand, Papua New Guinea, and neighboring Pacific islands. As all 14 countries are islands, much of the wildlife is unique, and the landscapes are largely unspoiled. Settlers from Southeast Asia first arrived in Australia thousands of years ago. By the 18th century, European immigrants had reached the region, which is now home to more than 30 million people.

Diamonds



Gold nugget

There are about 27.6 million sheep in New Zealand. Some are sheared for their wool

The Three Sisters is a distinctive rock formation in the Blue Mountains, Australia

TOURISM

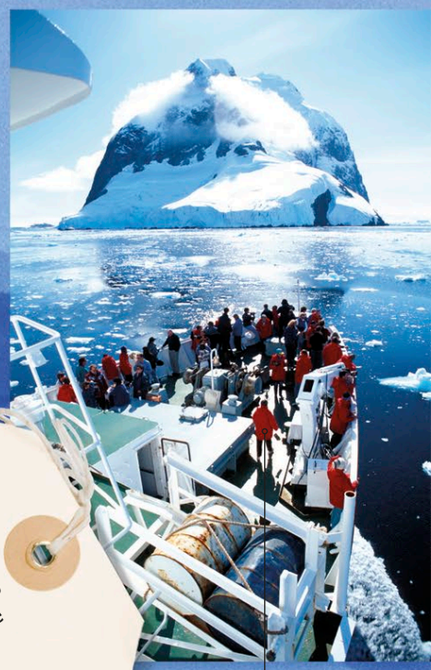
Australia and New Zealand are popular tourist destinations all year round thanks to the stunning scenery. Bustling harbor cities, such as Sydney and Auckland, offer a mix of beach life and culture. Famous buildings include the Sydney Opera House and Sydney Harbour Bridge.

Sydney Opera House

The Amundsen-Scott research base is named after the two famous expedition leaders who raced to reach the South Pole in 1911

Telescopes at Concordia research base provide astronomers with exceptional views of the clear skies above Antarctica

RESEARCH
About 70 permanent and more than 100 temporary research stations have been set up in Antarctica. Scientists analyze Antarctica's weather, climate, wildlife, and geology. Projects include monitoring ice samples to detect changes in the atmosphere and tracking penguins.



Tourists stay on board the cruise ships overnight as there are no resorts

TOURISM
Since the 1950s, cruise ships have brought tourists to Antarctica, and today, about 50,000 people visit each year. They either arrive by ship or take sightseeing trips by plane over the South Pole, the southernmost point on the planet. Insulated clothing and goggles are essential at all times.

ANTARCTICA

In the coldest continent on Earth, the temperature can drop to –112°F (–80°C), and human skin can freeze in seconds. Yet, thanks to scientists who are specially equipped to brave this harsh habitat, research on some of the world's most remote landscapes and wildlife is underway. Only discovered in 1820, Antarctica covers 5.5 million sq miles (14 million sq km), and, incredibly, 98 percent of it is covered with ice.

The largest penguin of all, the emperor penguin huddles in groups to keep warm during blizzards

Despite their name, crabeater seals eat krill (tiny marine creatures)

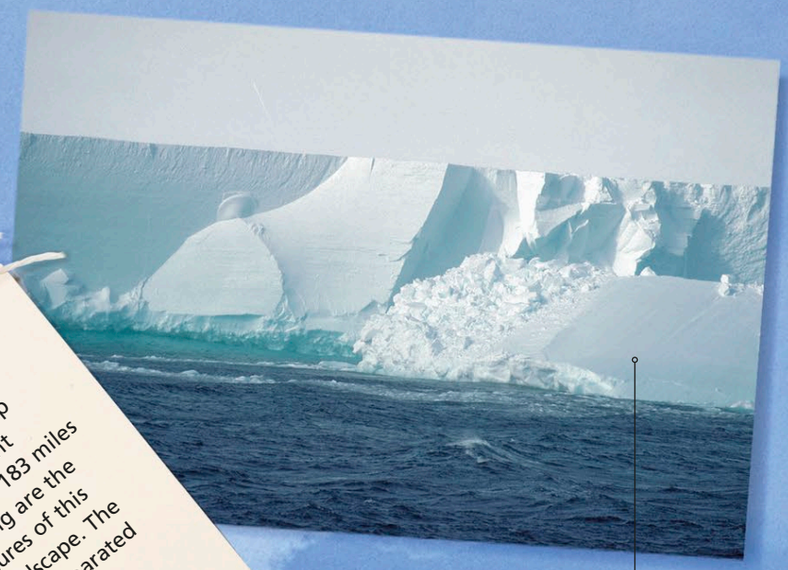
Humpback whales are sociable mammals, preferring to eat and travel in groups, which are called pods

WILDLIFE
Animals face a struggle for survival in Antarctica, but fish, seals, and whales can thrive in the sea. The Antarctic Peninsula has the mildest climate of the continent, making it a hub for wildlife. In summer, millions of seals and birds breed on the peninsula and nearby islands.

Mount Erebus on Ross Island is the southernmost active volcano in the world

LANDSCAPE

Dramatic seas, steep glaciers, and giant icebergs up to 183 miles (295 km) long are the main features of this unique landscape. The continent is separated into east and west Antarctica by the Transantarctic Mountains, which stretch for 2,175 miles (3,500 km).



Ice shelves form where the land ice meets the sea, with Ross Ice Shelf the continent's largest

Ice cores are samples taken by scientists for use in the study of global warming

CLIMATE

In winter, the Southern Ocean freezes, and the ice cap of Antarctica almost doubles in size. In summer, the temperature rarely rises above freezing. Less than 2 in (5 cm) of snow falls a year, making the area drier than the Sahara Desert. With gales blowing at more than 185 mph (300 km/h), it is the windiest continent, too.

SOUTHERN OCEAN
Scotia Sea
Weddell Sea
Riiser-Larsen Sea
Bellinghausen Sea
Antarctic Peninsula
Larsen Ice Shelf
Wilkins Ice Shelf
Brunt Ice Shelf
Filchner Ice Shelf
Ronne Ice Shelf
Fimbul Ice Shelf
Dronning Maud Land
Coats Land
Enderby Land
Kemp Land
Mac Robertson Land
Amery Ice Shelf
Princess Elizabeth Land
West Ice Shelf
ANTARCTICA
South Pole
Transantarctic Mountains
Ross Ice Shelf
Wilkes Land
Shackleton Ice Shelf
Vincennes Bay
Terre Adélie
Porpoise Bay
George V Land
Dumont d'Urville Sea

FLAGS

Historically, army leaders carried flags into battle as a rallying point for the soldiers. Today, flags are used to decorate buildings, mark public events, start races, honor the dead, or spell out messages or warnings from one ship to another. But by far the most recognizable ones are national flags–vibrant in color and unique in symbolism. Organizations and citizens fly the flag for their countries, building up a strong sense of identity, pride, and unity.

1 **AUSTRALIA**
The flag features a combination of the United Kingdom's flag, the Commonwealth Star (with its points symbolizing the original states of Australia), and the Southern Cross constellation (only visible in the Southern Hemisphere).

2 **SOUTH KOREA**
A red and blue Yin Yang symbol on the South Korean flag represents the Chinese philosophy that everything in the universe has an opposite. The four surrounding trigrams (groups of three lines) represent the ideals of balance, circulation, harmony, and symmetry.

3 **INDIA**
At the center of the tricolor (three colors) is the *ashoka chakra*, meaning "wheel of law." This symbolizes the hope that the country will continue to move forward peacefully.

4 **USA**
This flag is nicknamed the "Stars and Stripes." The 50 stars represent the states of the Union, while the red and white stripes are the 13 original colonies to join the Union.

5 **KENYA**
Since 1963, Kenya's flag has been dominated by a shield and spears, used by the country's Masai people. This symbol shows how the nation is determined to defend its freedom.

6 **MEXICO**
Traditionally, these colors had religious and military connotations, but the new meanings are defined as hope (green), unity (white), and the blood of heroes (red). The central image is a symbol from an earlier Aztec heritage.

7 **GERMANY**
During the Napoleonic wars of the 19th century, German soldiers wore black uniforms with red braid and gold buttons. These became the country's official colors, appearing on the national flag. Public buildings often fly the flag vertically.

8 **IRELAND**
This has been the flag of Ireland since 1919. The orange stands for Protestants, the green for Catholics, and the white for the peace between them.

9 **SPAIN**
This young flag was established in 1981. On the left-hand side, where the flag gets hoisted, is the Spanish coat of arms, which includes the royal seal.

10 **JAMAICA**
The flag of this Caribbean country shows a gold diagonal cross, which embodies the shining sun, green, for the fertile land, and black, which represents strength and creativity.

MAPS

Maps provide visual representations of the world, revealing the layout of our planet in a variety of ways. Some depict Earth's geographical features or the borders and boundaries between nations. Other maps detail road routes and street names or aid navigation on urban transportation networks. Scales on maps can be used to figure out real distances, and keys explain map symbols.

SATELLITE IMAGE

Space satellites are used to photograph Earth, capturing its surface in great detail. Orbiting thousands of miles above the planet, satellites track changes in the land, the ocean, and the atmosphere.

STREET MAP

Useful tools for navigating cities and towns, street maps include road names and notable landmarks, such as railroad stations, hospitals, churches, and parks. Street maps are available online and via some cell phones.

BUILDING PLAN

When planning a new structure, engineers first map out the building. Details such as layout, walls, and entrances are marked to assist workers during the construction. Precise measurements are added to give the true size of the project.

GEOLOGICAL MAP

Different rock types are coded by color on geological maps. Geologists study these maps to determine the location of minerals and oils, while structural engineers ensure rock types suit their construction plans before laying foundations.

SAILING CHART

Nautical maps of coastal or ocean areas are called charts. They include information about tides, currents, depths, potential hazards, and features of the seabed. Sailors carry these charts onboard their ships to help with marine navigation.

POLITICAL MAP

National and state borders are shown on political maps. Contrasting colors highlight different countries, so the legal boundaries stand out more clearly. To aid understanding, major cities, rivers, seas, and major cities are also labeled.

ROAD MAP

This visual aid for drivers is the most commonly used map of all. Covering a much larger area than a street map, road maps use different colors and lines to represent highways, main roads, and country roads.

PHYSICAL MAP

Permanent natural features are depicted on physical maps. Deserts, mountains, lakes, rivers, and oceans are identified, as well as the contrast between high and low land. Some physical maps go into more detail, pointing out land use and soil type.

ALLIANCES

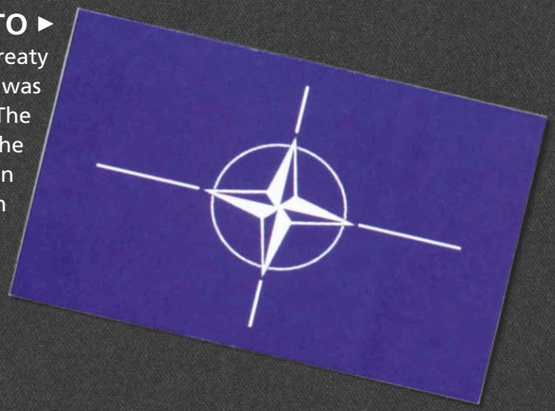
All over the world, groups of people or nations come together for common causes. The unions they form are called alliances. With financial backing and international influence, these alliances pursue shared goals.

UN ▲
After World War II ended in 1945, the United Nations (UN) was set up to promote peace. Today, the UN also plays a part in human rights, economic development, and fighting disease.

INTERPOL ►
Established in 1923, Interpol helps national police forces cooperate on criminal cases across countries.

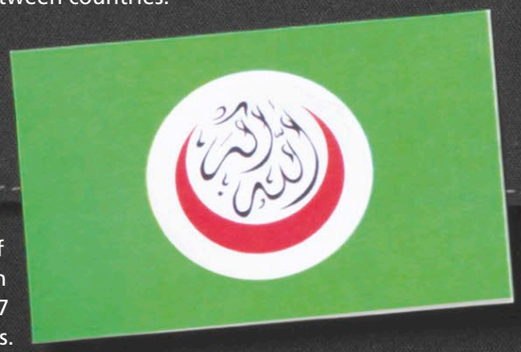
WORLD BANK ▲
The World Bank was founded in 1944 to help rebuild postwar Europe. Today, it gives poorer nations financial and technical assistance.

NATO ►
The North Atlantic Treaty Organization (NATO) was established in 1949. The alliance protects the safety of its American and European members.



▲ WORLD TRADE ORGANIZATION
Created in 1995, this is the only international organization managing the laws of trade between countries.

OIC ►
In 1969, Islamic leaders formed an alliance to protect Muslim interests. Today, the Organization of Islamic Cooperation (OIC) has 57 member nations.



OPEC ►
The Organization of Petroleum Exporting Countries (OPEC) consists of 15 of the largest oil-producing nations. Its goal is to ensure there is a regular and constant supply of oil.

LA FRANCOPHONIE ▲
About 220 million people speak French worldwide. To celebrate this, a group of French-speaking nations set up La Francophonie in 1970 to promote French language and culture.

EU ▲
The European Union (EU) was created in 1993 to ensure that goods, services, finance, and labor could move freely between member nations.

CIS ►
After the communist Soviet Union collapsed in 1991, leaders of the new republics formed the Commonwealth of Independent States (CIS). Its 12 states coordinate foreign and economic policy.

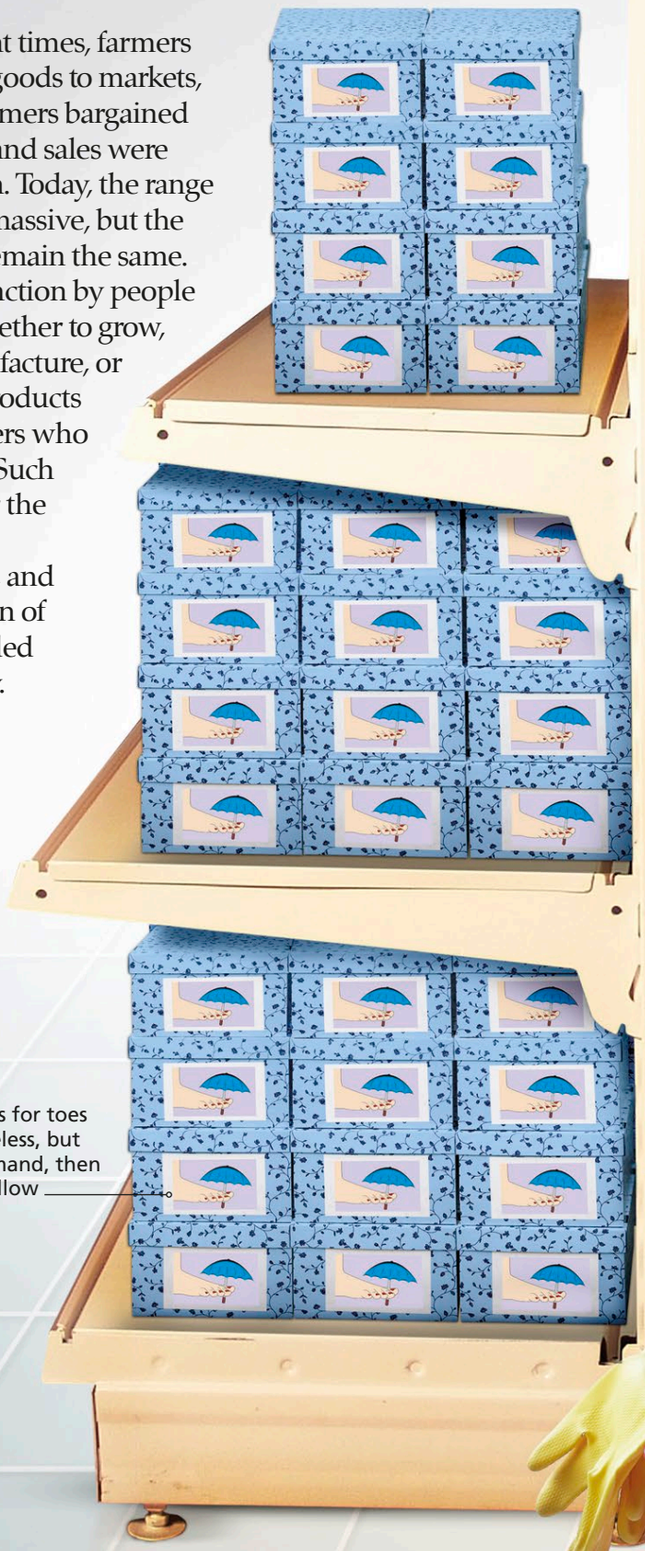
LATIN UNION ▼
Languages such as Italian, Spanish, and French are derived from the Latin of Ancient Rome. The Latin Union was founded in 1954 to preserve and promote the common heritage of countries with Latin-based languages, until 2012 when it was dissolved.

◄ AFRICAN UNION
In 2001, the African Union was established to reduce conflict and poverty across Africa. With its headquarters in Ethiopia, the organization has 55 member nations.

ASEAN ►
In 1967, Thailand, Indonesia, Malaysia, Singapore, and the Philippines founded the Association of Southeast Asian Nations (ASEAN). Today, 10 member nations share the goals of peace and economic growth.

ECONOMY

Since ancient times, farmers have taken goods to markets, where customers bargained over prices and sales were agreed upon. Today, the range of goods is massive, but the principles remain the same. Societies function by people working together to grow, build, manufacture, or distribute products for consumers who want them. Such a system, for the production, distribution, and consumption of goods, is called an economy.



These umbrellas for toes might seem useless, but if there is a demand, then a supply will follow

PRODUCTION

Every country uses its raw materials and its people to make all kinds of products to sell. The best ways to maximize profit are to reduce production costs, pay the workforce less, and use the speediest manufacturing tools. As production increases, so the economy grows.

TRADITIONAL ECONOMY

In less wealthy countries, a traditional economy is more common. People produce a few goods for themselves and sell what is left. Rural farmers may grow produce such as fruit and vegetables to feed their families and then sell the rest at local markets.

SUPPLY AND DEMAND

An economy works because there are people supplying goods and services to people who will pay for them. When there is a big demand, the price of these goods and services goes up, but if there is a huge supply, the prices drop to encourage the demand.

DOMESTIC WORK

Any unpaid work done at home is not counted as part of the economy. Housework, for example, contributes to the market economy only if a cleaner is paid for the job.

COMMAND VERSUS MIXED

The government takes control in a command economy and is in charge of the country's economic activity. However, in a mixed economy, some industries, such as health and transportation, are publicly owned and run by the government, but the rest are privately owned.

RAW MATERIALS

Some goods are used to create a different product. These are usually raw materials or partly finished items, such as steel, coal, wood, and paper. These goods are often unrecognizable in the final product.

CONSUMER GOODS

Producers must recognize what people want in order to create consumer goods that will prove popular, sell well, and increase profit. A wide range of goods, such as cars, clothing, toys, and food, are offered by many different producers to ensure that individual consumer needs are satisfied.

German flag

French flag

In times of war, governments can call upon citizens to fight for their country

CITIZENSHIP ▲

People born into a country or state are called its citizens. This gives them the right to protection by the government as well as the right to vote. Along with rights come responsibilities, and citizens are expected to abide by the laws of the land. Immigrants and refugees can sometimes become citizens of another country. Each country or state is identified by its national flag.

PROTEST ▼

If the citizens of a state or nation do not agree with the actions or policies of the ruling government, they sometimes rally together to stage a public protest. Often marching to the government's headquarters, people voice their concerns in an attempt to bring about change.

A passport is an official government document that allows each citizen to travel abroad

Protesters demonstrate outside the Philippine presidential palace in 2007

Megaphones are often used by protesters to make their voices heard

THE STATE

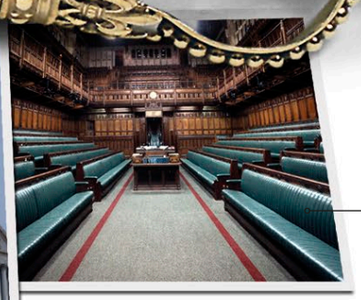
Throughout history, countries have been run by a variety of leaders and governments. At one time, heads of state were royalty, ruling with absolute authority. In many countries, power has now passed to the people, as democratic elections have replaced royal rule. Many citizens have the right to vote for their political leaders and to protest against them when necessary. Having won a place at the forefront of government, prime ministers and presidents run many world states.

Ceremonial mace is kept in the UK's House of Commons

LEGISLATURE ▶

States have elected representatives who are responsible for making laws, known as legislating. Government members debate new policies or changes to existing laws. Once the laws have been agreed upon, they are officially drafted by the legislatures. These laws must then be followed by all citizens.

United States Congress where new laws are passed



In the House of Commons, ministers debate changes to law and government policy

Wigs are worn by judges in some countries as part of legal tradition

A ballot box is a locked container into which citizens place their confidential votes

◄ LAW AND ORDER

A country's judges, collectively called the judiciary, make rulings on criminal allegations or civil disputes in courts of law. They interpret and uphold laws passed by the government before delivering their verdicts to the citizens involved. The law in most countries is upheld by a police force.

German police cap

Colored rosettes are sometimes worn by members of political parties to show their allegiance in the run-up to an election

DEMOCRACY ▲

In democratic societies, citizens have the opportunity to vote for their preferred candidate from a range of political parties. On election day, people cast their vote, and the party with the majority is established as the new government.

A gavel and block used by a judge to maintain silence in court

United States presidential seal

Presidents in South America, such as Chile's former leader Michelle Bachelet, wear sashes as symbols of office

◄ MONARCHY

In the past, most countries were ruled by a king or a queen, and, as head of state, the monarch's word was considered law. Although some countries still maintain a monarchy, their role is mainly ceremonial. It is the elected government that generally takes responsibility for how the country is run.

Crafted with priceless gems in 1838, the State Crown was first worn by British queen Victoria

REPUBLICS ▲

Countries that have a president as their head of state instead of a king or queen are called republics. Presidents can be elected by the citizens or appointed by the legislature and usually act as head of the nation's government.

This imperial seal of China shows a dragon guarding a pearl, which represents wisdom

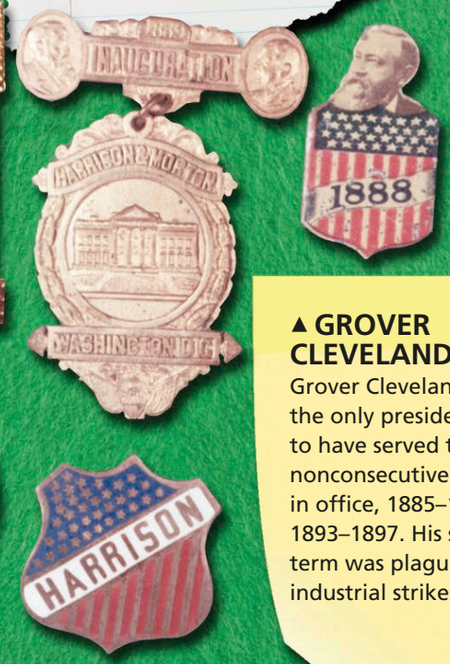
US PRESIDENTS

The United States is a superpower, dominating global affairs. The nation's head of state, the president, is regarded as one of the most powerful people in the world. Presidential elections are followed closely by other countries, since political decisions made by the US president can impact the rest of the world. The president serves a term of four years and, today, can hold office for a maximum of two terms.

ABRAHAM LINCOLN ▶
A passionate opponent of slavery, Lincoln led the Union States to victory in the Civil War of 1860–1865. His speech at Gettysburg, on the principles of human equality, is one of the greatest in American history.

JAMES GARFIELD ▼
The 20th US president was James Garfield, an army general. In 1881, he was assassinated after less than four months in office.

BENJAMIN HARRISON ▼
Electricity was first installed in the White House during the Harrison presidency (1889–1893)— his wife would not touch the switches, fearing electrocution.

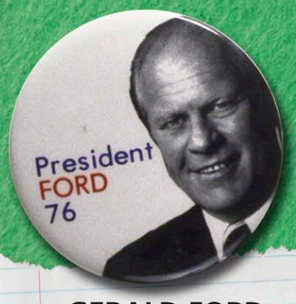


▲ GROVER CLEVELAND
Grover Cleveland is the only president to have served two nonconsecutive terms in office, 1885–1889 and 1893–1897. His second term was plagued by industrial strikes.

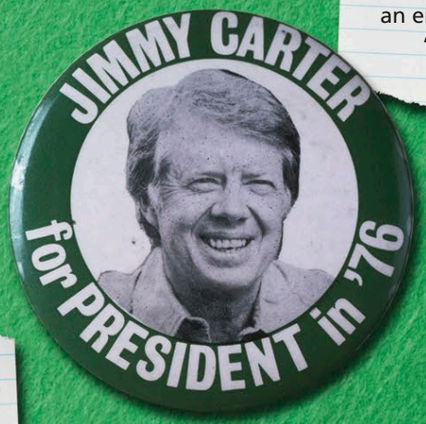
◀ HERBERT HOOVER
The Hoover presidency saw the Great Depression of 1929 and public opposition to prohibition (the banning of alcohol). He did not win a second term.

▲ FRANKLIN D ROOSEVELT
"FDR" served a record four terms in office from 1933–1945. He brought an end to the Depression with a "New Deal" to bring relief to the unemployed and took the US into World War II.

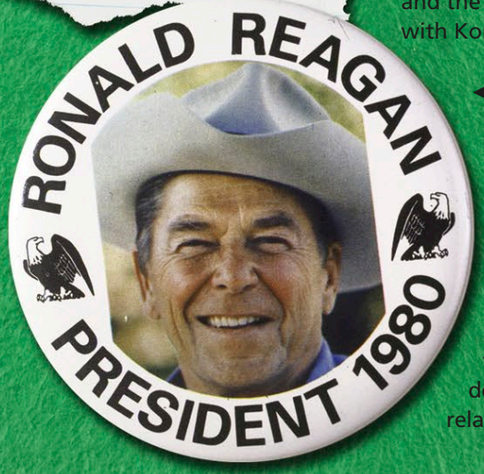
HARRY TRUMAN ▲
Truman saw the US through a difficult postwar period. The Cold War (period of tension with communist Russia) began, and the country went to war with Korea (1950–1953).



▲ GERALD FORD
Called to office after Nixon's resignation in 1974, Gerald Ford is the only president not to have been elected either president or vice president.

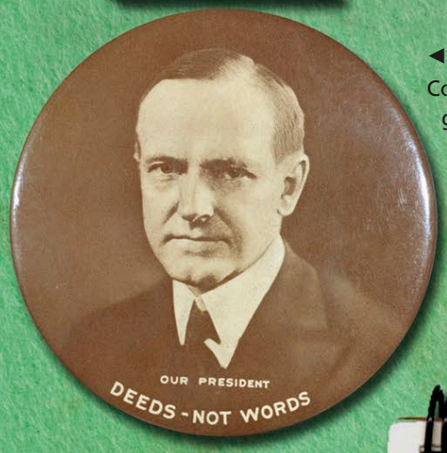


▲ JIMMY CARTER
During Carter's term of office, the US was beset by crises. At home, there was recession. Abroad, US citizens were taken hostage in Iran.



◀ RONALD REAGAN
Shortly after taking office in 1981, former Hollywood actor Ronald Reagan survived an assassination attempt. He went on to cut taxes, increase national defense, and improve relations with Russia.

THEODORE ROOSEVELT ▶
A reformer, Roosevelt promised a "Square Deal" for all. The teddy bear is named after Roosevelt, who refused to shoot a bear on a hunting trip.



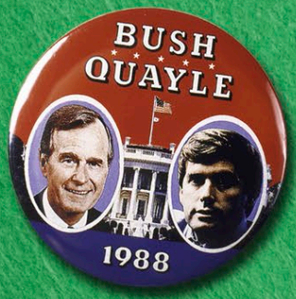
◀ CALVIN COOLIDGE
Coolidge believed the government should not control too many aspects of people's lives. A man of few words, he was nicknamed "Silent Cal."

WILLIAM McKINLEY ▶
The first to campaign using advertising techniques, McKinley won the 1896 election promising to tax foreign goods.

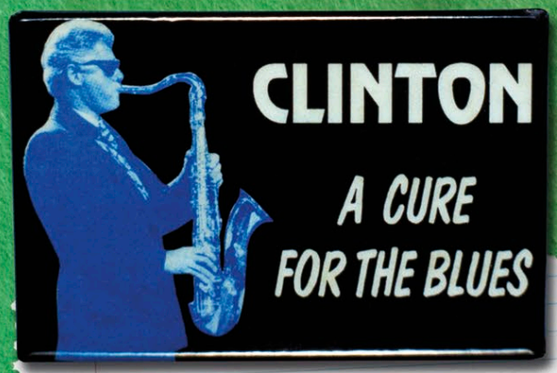
DWIGHT EISENHOWER ▲
Known as "Ike," Eisenhower launched the race between the US and Russia to explore outer space.

JOHN F. KENNEDY ▲
In 1961, "JFK" became the youngest elected US president, aged 44. Kennedy's leadership inspired hope. His assassination in 1963 left the country shattered.

RICHARD NIXON ▲
In 1974, Nixon became the only president to resign, because of his involvement in the Watergate scandal (illegal spying in the opposition party's headquarters).



GEORGE BUSH ▲
George Bush became president in 1989. From 1990–1991, he led an alliance of troops in the Gulf War in response to Iraq's invasion of Kuwait.



BILL CLINTON ▲
A long period of economic growth meant that, despite allegations of scandals, Bill Clinton always remained popular.

BARACK OBAMA ▲
The 44th president of the US, Obama was the first African American to hold the office and served for two consecutive terms.

George Washington	1789–1797
John Adams	1797–1801
Thomas Jefferson	1801–1809
James Madison	1809–1817
James Monroe	1817–1825
John Quincy Adams	1825–1829
Andrew Jackson	1829–1837
Martin Van Buren	1837–1841
William Harrison	1841
John Tyler	1841–1845
James Knox Polk	1845–1849
Zachary Taylor	1849–1850
Millard Fillmore	1850–1853
Franklin Pierce	1853–1857
James Buchanan	1857–1861
Abraham Lincoln	1861–1865
Andrew Johnson	1865–1869
Ulysses S. Grant	1869–1877
Rutherford Hayes	1877–1881
James Garfield	1881
Chester Arthur	1881–1885
Grover Cleveland	1885–1889
Benjamin Harrison	1889–1893
Grover Cleveland	1893–1897
William McKinley	1897–1901
Theodore Roosevelt	1901–1909
William Taft	1909–1913
Woodrow Wilson	1913–1921
Warren Harding	1921–1923
Calvin Coolidge	1923–1929
Herbert Hoover	1929–1933
Franklin D. Roosevelt	1933–1945
Harry Truman	1945–1953
Dwight Eisenhower	1953–1961
John F. Kennedy	1961–1963
Lyndon B. Johnson	1963–1969
Richard Nixon	1969–1974
Gerald Ford	1974–1977
James Carter	1977–1981
Ronald Reagan	1981–1989
George Bush	1989–1993
William Clinton	1993–2001
George W. Bush	2001–2009
Barack Obama	2009–2017
Donald Trump	2017–present

Bishop's miter This miter (hat) is worn by a bishop in the Roman Catholic Church, the largest Christian body.

Saint Anthony People who have led especially holy lives are named as saints by the Church.

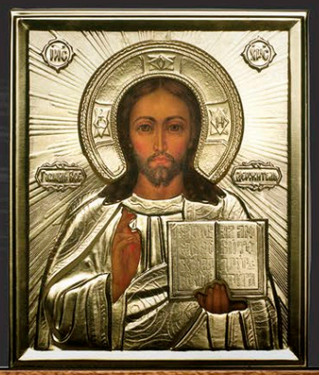
Cross Because Jesus died on a cross, it is a powerful symbol of the Christian faith.

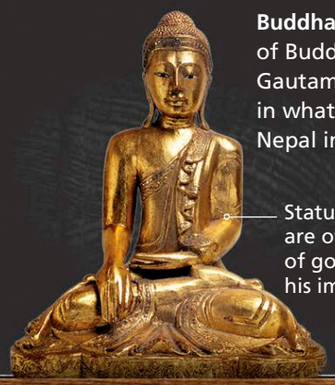
CHRISTIANITY

Christianity is based on the belief that Jesus Christ is God's son. The Bible, Christianity's sacred book, contains the story of Jesus's life and how he was put to death. Christians believe his sacrifice means that followers will have an eternal life with God.

Chalice In the ritual of Holy Communion, bread and wine represent the body and blood of Jesus. The wine is often served in a chalice.

Icon of Christ Paintings remind Christians that God lived as a human through Jesus.





Buddha The founder of Buddhism, Siddhartha Gautama, was born in what is now Nepal in 563 BCE.

Statues of Buddha are often made of gold to show his importance

Merit sharing Buddhists believe that if they live caring lives, they will build up merit (goodwill) and have a better next life. They can pass on merit to others in a merit-sharing ceremony.

In the temple, water is poured from one vessel to pass along merit to others

BUDDHISM

Unlike most religions, Buddhism is not based on worshipping a god or gods. Instead, it is based on the teachings of the Buddha, who showed his followers how to live a good life and avoid sufffering by controlling their desires. Buddhists hope to achieve true wisdom, known as enlightenment.

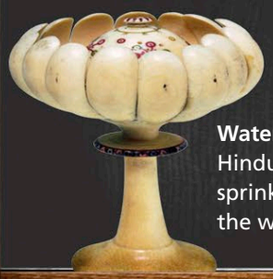
Menorah This nine-branched candlestick is used to celebrate Hanukkah, the Jewish festival of light. The central branch holds the candle used to light the others.

Prayer wheel and prayer As this Buddhist prayer wheel turns, a mantra (a blessing or prayer) written on a scroll inside "repeats" itself over and over again.

JUDAISM

This is the religion of the Jews, also called Hebrews. Judaism was the first successful religion based on the idea that there is only one God, and it formed the basis for both Christianity and Islam. Central to Jewish belief is that God chose the Jews as a special holy nation and gave them a set of laws to follow. The story of the first Jewish people is told in the Hebrew Bible (the Christian Old Testament).

Kippas Some Jewish men wear skullcaps, known as kippas, when they pray as a sign of respect to God.



Water shaker In one Hindu ritual, priests sprinkle water over the worshipers.

HINDUISM

One of the oldest religions, Hinduism began 5,000 years ago in India. Hindus believe in a supreme spirit, Brahman, who reveals himself through hundreds of gods and goddesses. Hindus practice their faith in different ways but share a belief in reincarnation—the idea that a person's soul has lived before and will live on after death in another form.

Ganesh Hindus pray to Ganesh, the elephant god of wisdom and help, when facing a new challenge.

Om This is an image of the sacred sound, Om, spoken after Hindu prayer.

Krishna This popular Hindu god is thought to bring great happiness to believers.

Krishna is usually shown as a smiling youth with sky-blue skin

Islamic scribe Because the Quran is believed to contain God's exact words, great care is taken when Muslim scribes re-create them.

Islamic tile The sacred words of the Quran appear on many decorative objects, such as this tile.

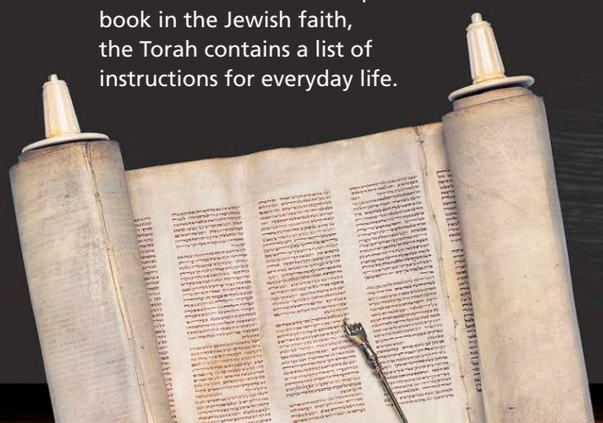
Prayer beads God, or Allah, is thought to have 99 names. This string of 99 prayer beads can be used to remind Muslims of the many names of the one God.

Qibla Muslims must face the holy city of Mecca when they pray, five times a day. This instrument helps them find its location.

ISLAM

Muslims believe that God revealed his words through an angel to the prophet Muhammad, who collected them in the Quran, the holy book. The faithful try to live by the rules in this book. The most important duties are the Five Pillars: prayer, helping the needy, fasting for one month a year, making a pilgrimage to Mecca, and showing faith in God.

Torah scroll The most important book in the Jewish faith, the Torah contains a list of instructions for everyday life.



RELIGION

A religion is a set of beliefs that helps explain life's mysteries. People seek guidance from their religion on how they should live their lives. Most people with religious faith believe in either one God or many gods. They express their faith through rituals, such as gathering together with others to worship, and by studying sacred books. There are many different religions, but those included here have the most followers around the world.

FESTIVALS

Across the world, people celebrate festivals for a range of reasons. Though many form part of religious worship, others were created to mark a change in seasons, to focus on cultural traditions, or to celebrate an important milestone in history. Some festivals take place on the same day every year; others are based on ancient calendars or a new moon, so the dates change. Special food is almost always a part of each festival.

❶ CHRISTMAS

This Christian festival celebrates the birth of Jesus Christ and is celebrated in most countries on December 25. Traditions include decorating fir trees, exchanging gifts, attending church, and waiting for a visit from Santa Claus.

❷ DAY OF THE DEAD

During this Mexican festival, held on November 1, families believe that the souls of dead relatives are able to return to the land of the living for one night. They decorate altars in homes and cemeteries with candles and flowers.

❸ THANKSGIVING

This North American festival is held on the fourth Thursday of November in the US and the second Monday in October in Canada. Families get together to give thanks for the first good harvest of the European settlers more than 400 years ago.

❹ DRAGON BOAT FESTIVAL

This festival is celebrated in east Asia. According to legend, when a Chinese official named Qu Yuan drowned in a river, people rowed out on boats with dragon-head prows and dropped parcels of rice wrapped in bamboo (*zongzi*) into the water to divert the hungry fish away from his body.

❺ MIDFALL FESTIVAL

This east Asian celebration, which dates back more than 3,000 years, falls near the traditional harvest, when the moon is at its lightest and brightest. Family and friends gather in the evening to eat mooncakes, rich rounds of pastry with lotus-seed fillings.

❻ FEAST OF ST. LUCIA

Each year, on December 13, people in Sweden and Norway celebrate the feast of Saint Lucia (a Christian girl who died for her faith). Early in the morning, a young girl dressed in white (often the youngest daughter in the house) takes a tray of hot saffron buns to her family.

❼ EID AL-FITR

This Muslim festival marks the end of Ramadan, a monthlong fast. The celebration lasts for three days, starting with the sighting of the new moon. People dress in their best clothes and go to the mosque.

❽ DIWALI

Also known as the Festival of Lights, Diwali celebrates the victory of good over evil. Hindu families light oil lamps and put them on ledges and balconies. They also send cards with wishes for a good year.

❾ PASSOVER

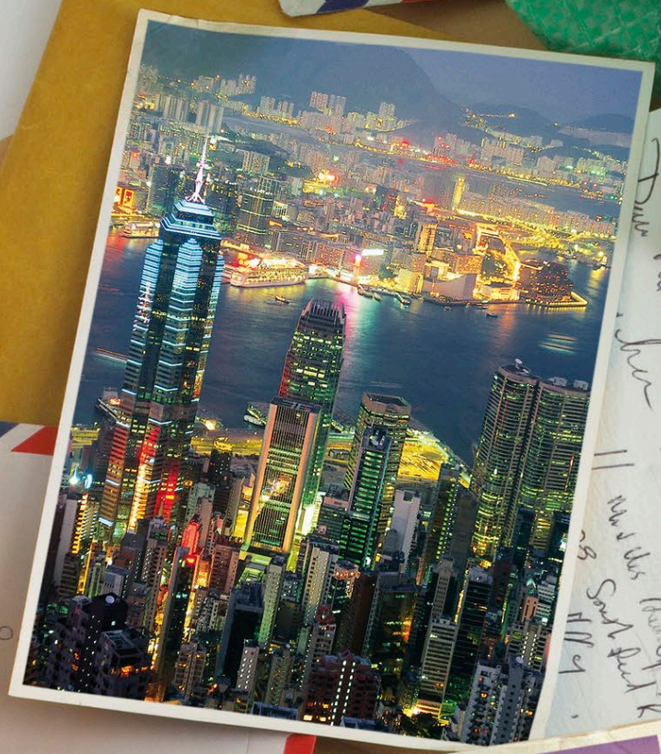
In March or April, Jews celebrate Passover to remember when Moses led the Israelites from slavery in Egypt. Passover lasts for seven or eight days and includes a special meal called a *seder*. Each part of the meal has a symbolic meaning.

❿ EASTER

The Christian festival of Easter recognizes the resurrection of Jesus on the third day after his death. It falls between late March and April each year. People attend church and exchange Easter eggs.

CITIES

Cities have existed since ancient times, when they functioned as trading hubs, often at the heart of sprawling empires. By the early 20th century, one in 10 people lived in a city. Industrialization has led to massive urbanization, and more than half of the world's population are now city dwellers. Modern cities are centers of commerce, culture, and government.



▼ CITY-STATE

In Ancient Greece, it was common for cities to establish themselves as independent states, with their own political systems. By the 5th century BCE, there were hundreds of city-states, and Athens was one of the most important. Today, Athens is the Greek capital.

HIGH-RISE ▶

The first high-rise buildings, now known as "skyscrapers," were constructed in the 1880s. With limited space in city centers, building upward became the solution. Today, more than 7,000 skyscrapers tower above the city of Hong Kong.

Modern Athens was built around the ruins of the ancient city-state

▲ RELIGIOUS CENTER

Some cities are important religious sites. Mecca, in Saudi Arabia, is sacred to Muslims as the birthplace of the prophet Muhammad. All Muslims should make a pilgrimage to Mecca once in their lifetime.

RIVER LIVING ▶

Towns and cities were often built next to rivers, to take advantage of the trading opportunities and transportation links they offered. Founded by the Romans, the city of London now spreads far and wide on both sides of the Thames River.

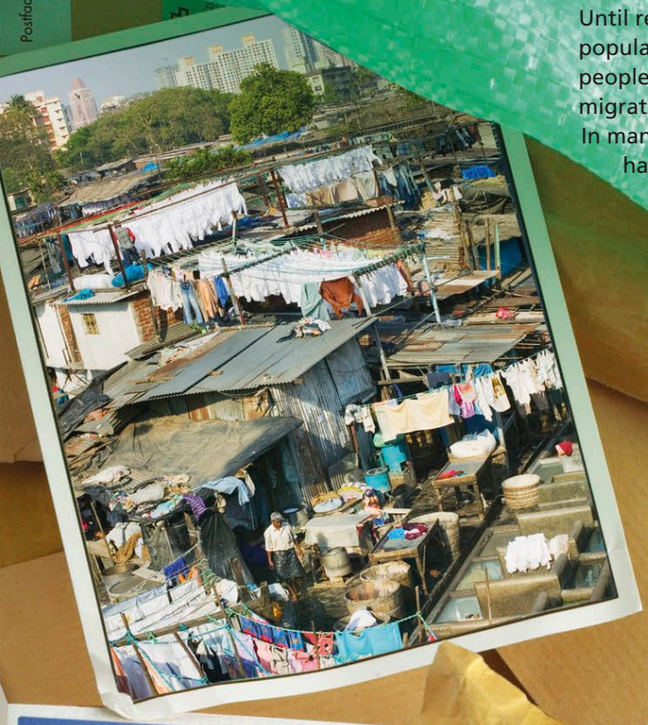
The Palace of Westminster is home to the British parliament

CONURBATION ▶

When a city expands to merge with neighboring towns, it becomes one huge urban area called a conurbation. The world's largest conurbation is Tokyo, Japan, with currently 37 million inhabitants.

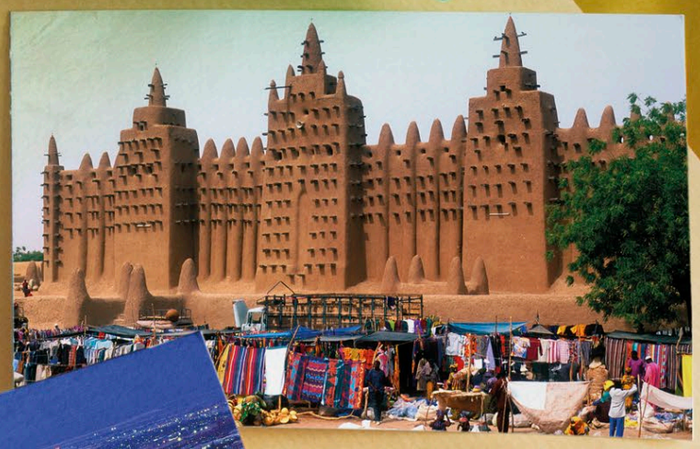
◄ POPULATION GROWTH

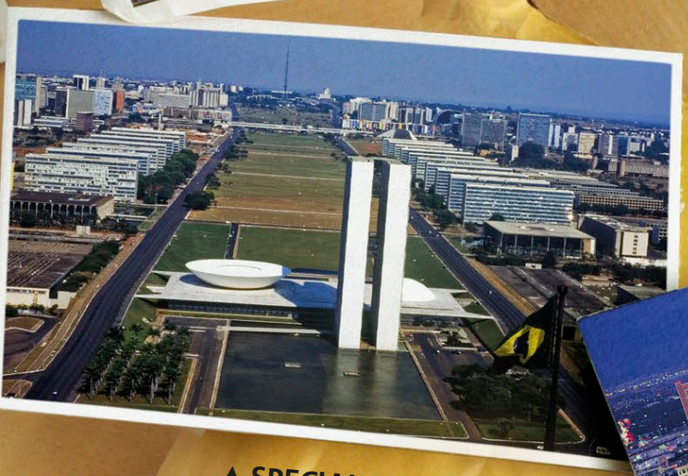
Until recently, the majority of the world's population lived in rural areas. Today, most people live in cities, where they have migrated in search of work and opportunity. In many cities, such as Mumbai in India, this has led to overcrowding as temporary shelters spring up on the outskirts.



WORLD HERITAGE ►

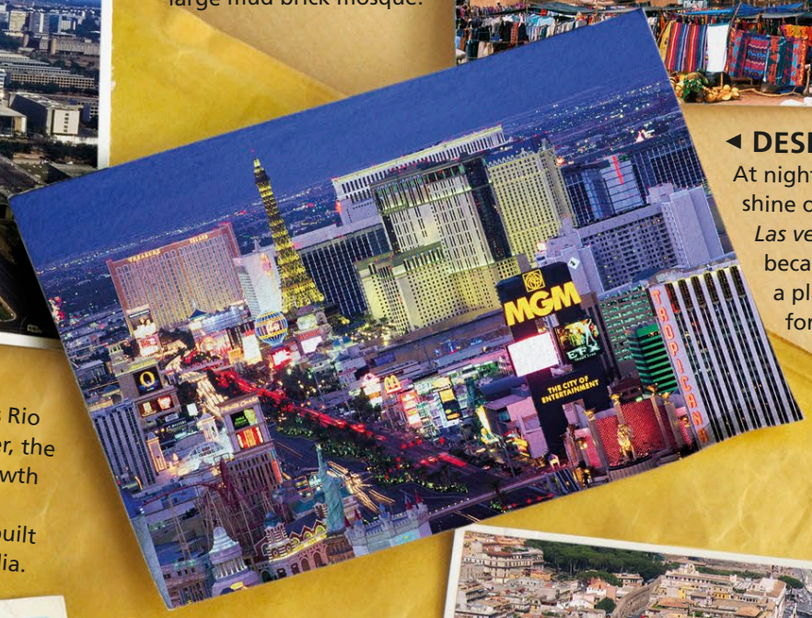
The United Nations Educational, Scientific, and Cultural Organization (UNESCO) has listed sites of outstanding cultural or natural importance in order to preserve them. Called World Heritage Sites, these include cities such as Djenné in Mali, with its large mud brick mosque.





▲ SPECIALLY BUILT

Until 1960, the capital of Brazil was Rio de Janeiro on the east coast. However, the government wanted to encourage growth and development in the center of the country, and so a brand new capital was built in the interior—the modern capital of Brasília.



◄ DESERT CITY

At night, the lights of Las Vegas shine out across the Nevada Desert. *Las vegas* means "the meadows" because the vast city was once just a place where travelers stopped for water as they crossed America.

CITY WITHIN A CITY ►

Few city-states remain today, but one exception is the Vatican City in Rome, Italy, home of the Pope and the center of the Roman Catholic Church. The Vatican remains a city-state with its own flag, coins, national anthem, and postage stamps.

EXTREME LIVING

Humans have found a way of living in some of the most inhospitable environments on Earth–including the scorching deserts, the icy Arctic, and the steamy rain forests. Desert dwellers have to cope with the daily problem of finding water. In the Arctic, the challenges are keeping warm and finding food to eat. The rain forests are full of life, but many of the animals are dangerous, and some of the plants are poisonous.

Tuareg headscarf Wound around the head and neck, this headscarf protects the Tuareg people from the blistering sun and sandstorms.

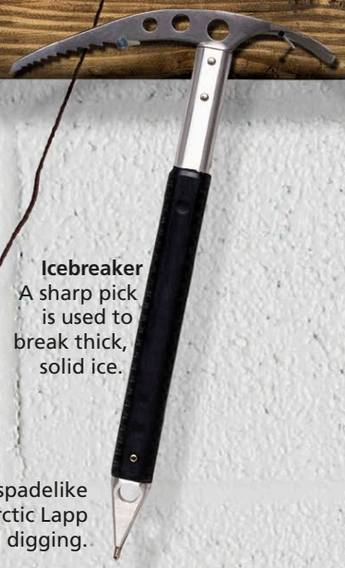
Sun hat Worn by the Fulani of West Africa, this hat shades the face.

Boomerang This throwing stick, was used by Australian aboriginals for hunting wild animals.

Snowmobile This motorized sled has skis for gliding over the snow.

ARCTIC

The frozen Arctic is one of the toughest places on Earth to survive. There are no plant foods, so Arctic people came to rely on hunting seals, walruses, whales, birds, and fish. Without lumber, they used skins and bones to build shelters, sleds, and boats. Modern inventions, such as the snowmobile, have made life in this frozen wilderness easier.



Icebreaker A sharp pick is used to break thick, solid ice.

Fishing rod Arctic dwellers fish through holes in the ice.

Lapp stick This stick with a spadelike blade is used by the Arctic Lapp people for probing and digging.

RAIN FOREST

Unlike the Arctic and the desert, the South American rain forest has a wide variety of animals and plants. The problem is that many of the animals and birds suitable for eating live high up in the canopy. Hunters scan the trees above for prey, such as monkeys, and then shoot them down using blowpipes firing poison darts.

Hammock The hammock allows people in the rain forest to sleep in midair, away from snakes and insects.

Poison dart frog This frog produces deadly poison, used to tip blowpipe darts.

Mosquito net Protection from insect bites is crucial when sleeping, since diseases like malaria are spread in this way.

DESERT

The extremes of temperature faced in the desert—extremely hot during the day and very cold at night—is the main problem desert dwellers face. They are constantly on the move, searching for freshwater supplies, sometimes using the flight of birds and insects as their guide. Having found water, they must make sure that not a drop is wasted.

Goatskin bag The Arabian Bedouin draw water from deep wells and transport it in goatskin bags.

Ostrich egg The San people of the Kalahari Desert, in southern Africa, fill ostrich eggs with water and bury them for using later.

Camels Bedouins travel using camels, which can go without water for long periods thanks to the fat stored on their backs.

Skin shoes The Sami of Northern Scandinavia wear shoes made of reindeer skin.

Traditional parka The Inuit of the Canadian Arctic wear thick, warm clothing made from caribou skins.

Modern Arctic clothes These are just as warm as the traditional wear but are lighter and more flexible.

House on stilts Rain-forest people build these as protection from flooding and creepy-crawlies.

Blowpipe Crafted from wood, blowpipes are used to hunt birds and monkeys.

BYZANTINE MOSAIC
This detail from a mosaic of colored tiles shows Theodora, wife of Emperor Justinian (ruled 527–565), with court officials. The Byzantine Empire, based in the eastern Mediterranean, was an offshoot of the Roman Empire.

History

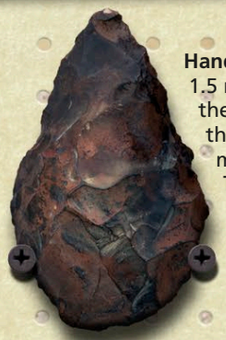
PREHISTORY

Our distant past, before writing was invented, is called prehistory. Without written records, we rely on the objects that prehistoric people left behind them, such as tools, to find out how they lived. The first tools, made around 2.5 million years ago, were of stone, bone, and wood. Later, prehistoric people learned to use metals–first copper, then bronze, and finally iron.

Polished ax This ax, with its polished flint blade, was used by farmers to clear land to create fields.

Sickle A long flint, mounted in a wooden handle, forms a farmer's sickle, used to harvest grain.

Chopper This chopper was made 2.5 million years ago, by chipping a pebble to make a cutting edge. It would have been used to smash bones to get to the marrow inside.



Handax Invented 1.5 million years ago, the handax was the first stone tool made to a design. The pointed end was used for cutting meat or digging up edible roots.

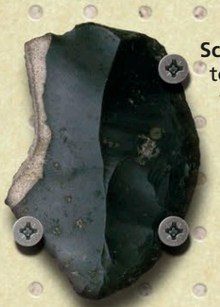
Flint blade

Adze This adze, with its flint blade set in a wooden sleeve, was used to shape wood.

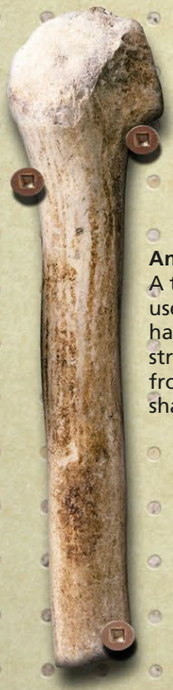
Flint

Iron pyrite

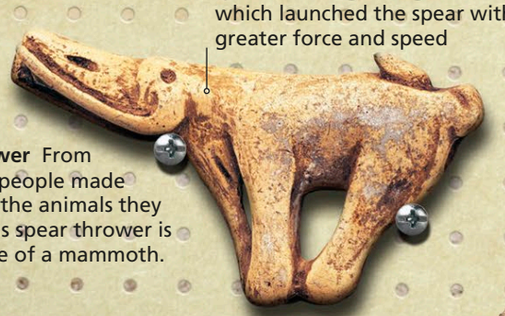
Making fire Prehistoric people learned to make fire by striking flints against lumps of iron pyrite.



Scraper The best stone tools were made from flint, which forms sharp edges. This tool would have been used for scraping animal skins clean.



Antler hammer A toolmaker used an antler hammer to strike flakes from a flint to shape it.



Mammoth-shaped hook held the spear in a long, straight handle, which launched the spear with greater force and speed

Spear thrower From 30,000 BCE, people made carvings of the animals they hunted. This spear thrower is in the shape of a mammoth.

THE AGE OF FARMING ▲

Between 10,000–9,000 BCE, people in the Middle East invented a new way of life—farming. They learned to store and sow the seeds of plants and to breed animals, such as sheep and goats. By controlling their food supplies, farming people were able to settle down in permanent villages. As the supply of food became more regular, populations rose, and the farming way of life spread.

Antler pick European farming people mined for flints, digging with picks made from deer antlers.

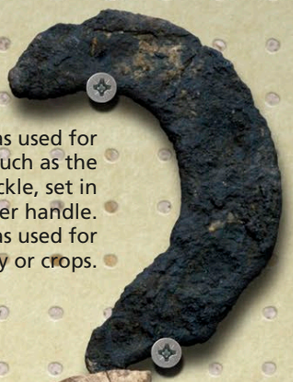
Arrowheads Farming people continued to hunt wild animals, using bows and arrows with skillfully shaped flint heads.

HUNTER-GATHERERS ▲

For most of prehistory, people lived by hunting animals and gathering wild plant foods. Hunter-gatherers lived in small bands, which were often on the move, following herds of animals and looking for fresh sources of food. The first humans lived in Africa but gradually spread across the globe, settling first Asia and then Europe. Humans reached Australia by 50,000 BCE and the Americas between 30,000–14,000 BCE.

COPPER AND BRONZE ▼

The next discovery was how to make tools from metals. Around 5,000 BCE, people in Europe and Asia learned how to extract copper by heating certain rocks. They used the bright metal to make tools and jewelry. Around 3,500 BCE, they discovered that adding a small amount of tin to copper made a harder metal, called bronze.



Sickle Iron was used for everyday tools, such as the blade of this sickle, set in an antler handle. A sickle was used for cutting hay or crops.

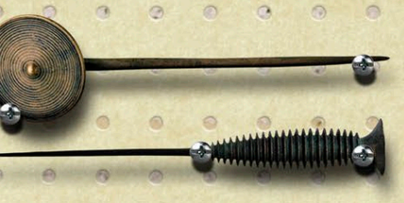
Neck ring This bronze neck ring was worn by a British Iron Age warrior as a protective charm.

Bronze sword The discovery of tougher bronze led to the invention of a new weapon—the sword. This one has been cleaned to show its golden color.

Royal dagger This bronze dagger, decorated with sea creatures in gold and silver, belonged to a ruler of Mycenae in Greece.

Iron dagger The scabbard of this iron dagger is decorated with bronze strips. It was found in the Thames River, England, and dates from c. 550–450 BCE.

Belt boss This decoration, which would have hung from a belt, was made by flattening a piece of bronze and hammering patterns into it.

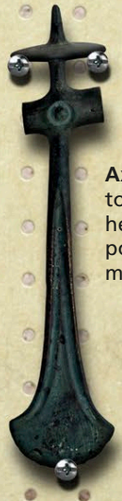


Bronze pin Bronze, with its gleaming golden color, was popular for jewelry among the rich. These pins were used to fasten clothes.

Spearhead This is the head of a huge spear, which would have been thrust rather than thrown. Together with its wooden shaft, it measured more than 7 ft (2 m).

Iron Age sword Iron made stronger swords than bronze. This fine iron sword, which is 2 ft 4 in (70 cm) long, was discovered in 1987 in an Iron Age grave. It is a rare find because iron objects are usually destroyed by rust.

Mirror This is the back of an intricately decorated bronze mirror. The other side was highly polished to give a reflection.



Ax head Bronze tools, such as this ax head, were made by pouring the molten metal into molds.

Short sword This Ancient Egyptian weapon has a smooth handle so that it could be gripped tightly. The blade is ridged for extra strength.

THE IRON AGE ▲

Although iron is the most common metal on Earth, it was the last to be used to make tools. Unlike copper and tin, iron does not melt when heated in a fire. People did not learn how to shape iron, by heating and beating it with a hammer, until around 1,550 BCE. While bronze was a metal for the rich, everyone could afford iron.

FIRST CIVILIZATIONS

More than 5,000 years ago, farming peoples in the river valleys of Mesopotamia (modern-day Iraq), Egypt, and India created the world's first civilizations. In Sumer, southern Mesopotamia, people known as Sumerians built the first cities. Each city was ruled by a king, who governed on behalf of the local god. This scene shows the king of the city of Ur receiving goods from his people.

❶ **King** Sumerians believed that kingship was handed down from the gods. This king wears no crown, but his importance is shown by his kilt and the fact that he is larger than everyone else.

❷ **Servants** Two men move between the king and his guests, bringing food and drink. Their low status is shown by their smaller size. They would have lived in the palace or in mud-brick homes.

❸ **Nobles** These men may have been priests, relatives of the king, or wealthy landowners. They are shown sitting on chairs with delicately carved legs, evidence of luxury at the palace.

❹ **Musicians** This man is shown playing a lyre, which has a wooden sound box decorated with the head of a bull. Other instruments from the time included harps, lutes, reed pipes, and drums.

❺ **Singer** The only woman in the scene is singing with the lyre player to entertain the guests. Music and dancing played a key role in religious rituals, such as giving thanks for a good harvest.

❻ **Farmers** Although the area was hot and dry, silt from the rivers kept the soil fertile. Farmers also dug canals to divert water to their crops, which included barley, turnips, onions, and dates.

❼ **Fishermen** Rivers offered a plentiful supply of fish for all early civilizations. From the Indus in India, the Nile in Egypt, and the Euphrates and Tigris in Sumer, fish were caught with nets or spears.

❽ **Animals** Sheep, goats, cattle, and pigs were vital to the first civilizations. They provided meat, milk, leather, and wool. Oxen were used to pull plows and donkeys for transportation.

❾ **Workers** This man carries a bundle on his back, the heavy load strapped to his head. It was thanks to the toil of workers like this that massive temples for the gods could be built.

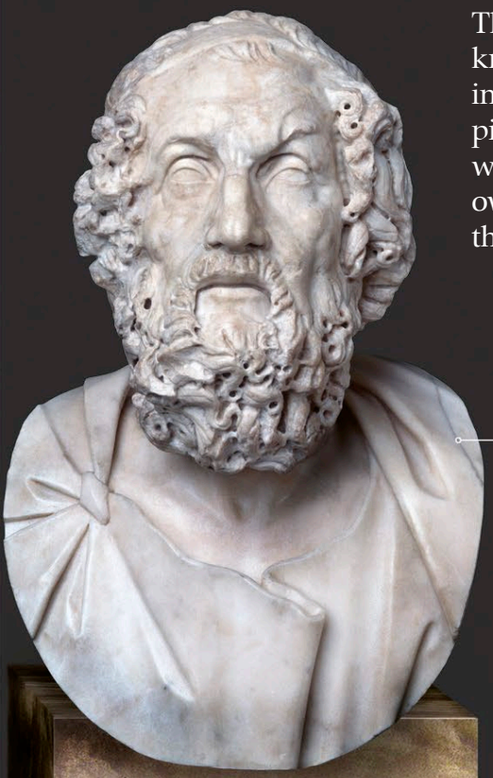
❿ **Clothing** Made from either wool or flax, both men and women wore tufted kilts, designed to resemble sheepskins. Wealthy men and women also owned elaborate gold jewelry.

▲ THE STANDARD OF UR

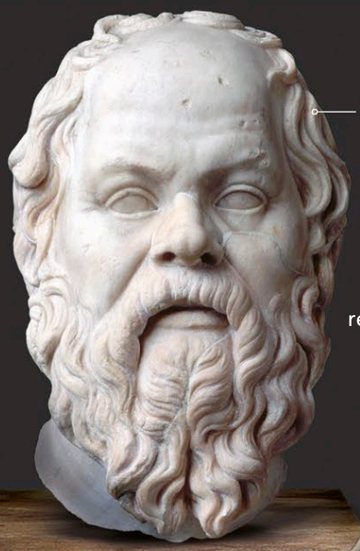
This mosaic of blue lapis lazuli, red sandstone, and white shell was made in the city of Ur in about 2,500 BCE. It decorates one side of a small wooden box found in a royal grave. The purpose of the box is not known. This side shows a peaceful banquet, while the other side depicts scenes of war.

CLASSICAL WORLD

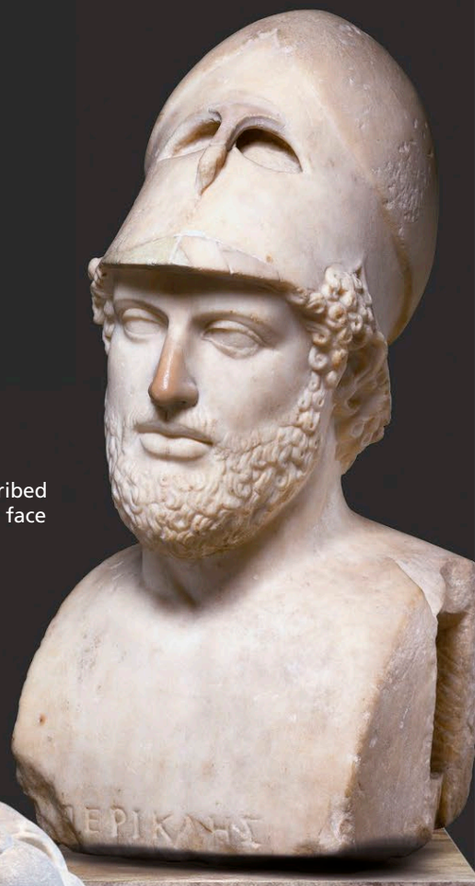
The civilizations of Ancient Greece and Rome are collectively known as the "classical world." The word "classical," in this instance, refers to culture of the highest quality. The Greeks were pioneers in science and the arts. They influenced the Romans, who spread this style of art, architecture, and literature across their own empire. Men in both societies were eager to find fame, often through military might.



Although little is known about Homer's life, it is generally thought that he was blind



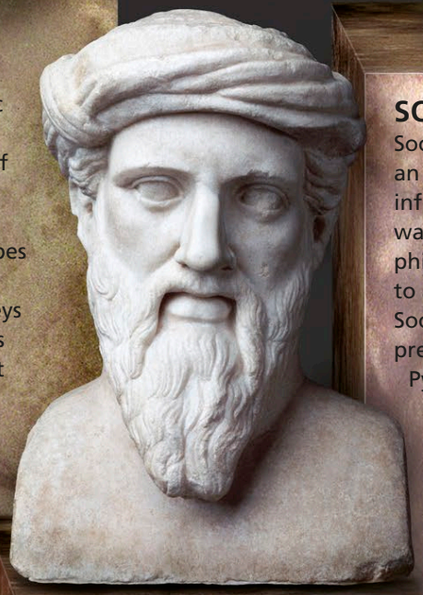
Socrates was described as having a round face and a snub nose



Lionskin headdress of legendary hero Heracles, renowned for his superhuman strength

HOMER

During the 8th century BCE, Homer wrote two great epic poems about the legendary Greek war against the city of Troy. The *Iliad* recounts the story of the Greek warrior Achilles. The *Odyssey* describes the adventures of another hero, Odysseus, as he journeys home after the war. Homer's writing is so powerful that it is said to have influenced writers through the ages. He was so important to the Greeks that they simply called him "the poet." Homer's poems were originally sung or chanted to the accompaniment of a lyre.

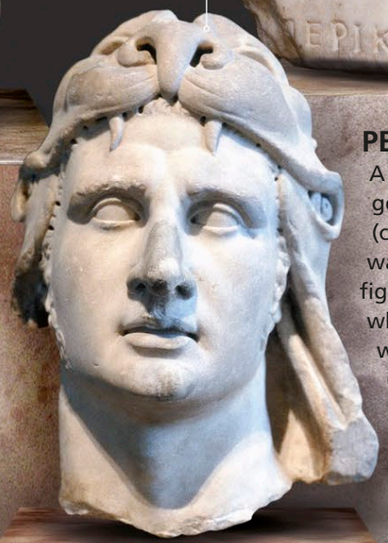


PYTHAGORAS

A philosopher, astronomer, and mathematician, Pythagoras lived in the 6th century BCE. He is remembered today for his work in geometry—particularly his theorem about triangles—but he was also a religious teacher. Pythagoras wanted to unlock the secrets of the universe and saw mathematics as the key to everything. He believed that numbers were the ultimate reality.

SOCRATES

Socrates (469–399 BCE) was an Athenian thinker whose influence on philosophy was so great that all earlier philosophers are referred to as "pre-Socratic" (before Socrates). However, unlike previous thinkers, such as Pythagoras, Socrates did not try to understand the universe. He believed that it was more important to find the best way to live. Accused by his enemies of being a bad influence, he was put on trial and sentenced to death by drinking poison.



ALEXANDER THE GREAT

One of the world's greatest generals, and bravest of soldiers, Alexander (356–323 BCE) was king of Macedon, to the north of Greece. After forcing the Greeks to unite under his leadership, he conquered a vast empire, stretching from Egypt to northwest India. By the time of his death, aged just 32, he had won lasting fame and was forever known as Alexander the Great.

PERICLES

A statesman and general, Pericles (c. 495–429 BCE) was a leading figure in Athens when the state was a democracy (meaning "power by the people"). He filled Athens with temples, such as the Parthenon, which was dedicated to Athena, goddess of the city. Pericles also promoted the arts and made Athens the cultural center of Greece.

JULIUS CAESAR

Politician, general, and writer, Julius Caesar (c. 100–44 BCE) is famous for his conquest of Gaul (modern-day France), which he described in his book *The Gallic Wars*. He also fought and won a civil war against a rival Roman general, Pompey. Caesar marched on Rome and was declared dictator for life. He was later murdered for acting like a king, which went against the principles of the Roman republic.

EMPEROR AUGUSTUS

Augustus (the revered one) was the title given to Julius Caesar's adopted heir, Octavian, when he became Rome's first emperor. Augustus (ruled 27 BCE–14 CE) took power after defeating his rival, Mark Antony, in battle. He ruled Rome for more than 40 years and brought peace and stability to the empire after years of civil war.

TRAJAN

A Spaniard by birth, Emperor Trajan (ruled 98–117 CE) was the first Roman ruler to be born outside Italy. He was a successful general, and his conquests in the Balkans and what is now Iraq brought the Roman empire to its largest size. In Rome, a famous column was built in his honor decorated with scenes of his campaigns.

AGRIPPINA

The wife of Emperor Claudius, Agrippina (15–59 CE) was a powerful and ambitious woman. She persuaded her husband to adopt Nero, her son from a previous marriage. She is thought to have then poisoned Claudius so that the 16-year-old Nero could come to the throne. At first, Nero was dominated by his mother, but he eventually grew tired of her interference and had her murdered.

SULLA

As a Roman general, Sulla (138–78 BCE) was a ruthless and ambitious man. His quarrels with a rival general, Marius, led to the first in a series of bloody civil wars—in which Romans fought against each other. Sulla was the first general to march on Rome as the head of an army and seize power. Julius Caesar later followed his example.

The castle was a fortress and a garrison for soldiers

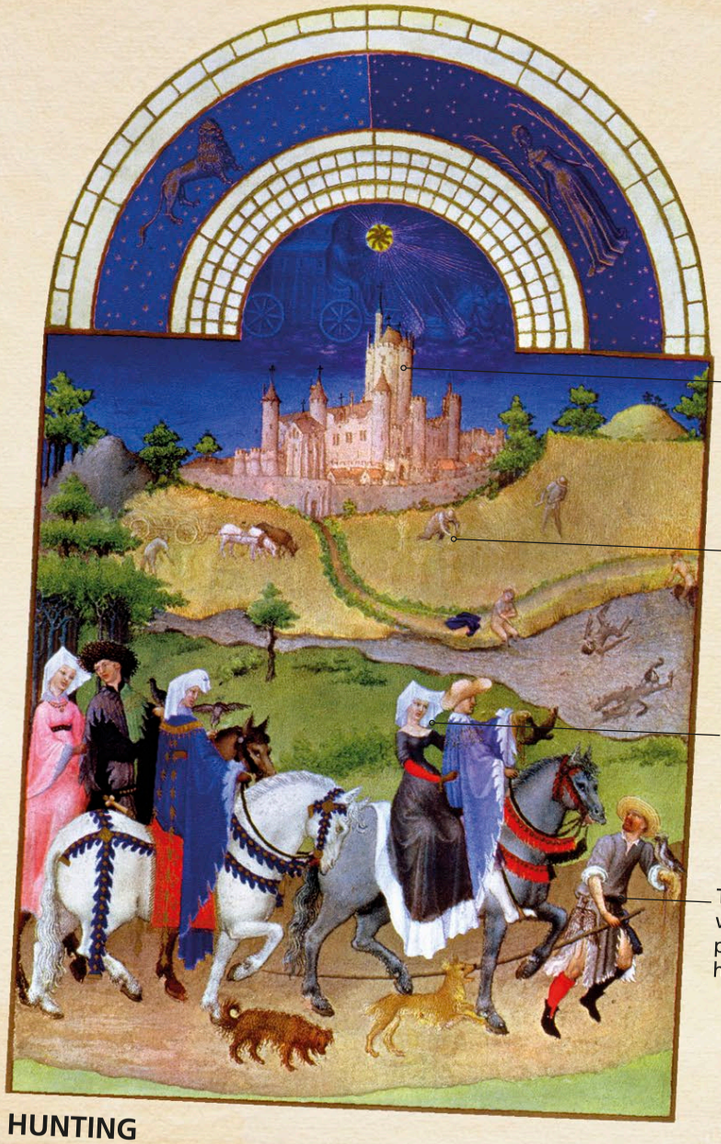
Vineyards surrounded by walls

A peasant sows seeds—like most farm work, this had to be done by hand

Peasants had few rights—they could not marry or leave the village without the lord's permission

FEUDAL SOCIETY

Medieval society was organized into a "feudal system," based on giving land in exchange for service. At the top was the king who granted land to his nobles. In return, the nobles supplied the king with soldiers. At the bottom were the peasants who worked the land in exchange for a piece of land to farm for themselves.



Castles were the stately homes of France's richest nobles

Wheat was cut using a curved blade called a sickle

Women covered their hair with a linen headdress called a wimple

The falconer was a well-paid professional huntsman

HUNTING

The Duke of Berry was a very powerful man and had many castles and lands. This painting shows his castle at Etampes, where a group of richly dressed nobles take birds of prey to hunt partridges, swans, ducks, pigeons, and other birds. Throughout the Middle Ages, hunting was the favorite sport of the rich.

The castle was designed both to show off the lord's power and wealth and repel enemy armies

Drawbridge

The low wall at the tournament ground separated the knights as they charged each other on horseback armed with lances

Peasant life was harsh, and many children did not live beyond the age of 10

CASTLE BUILDING

In September, the grapes were harvested, as seen here in the grounds of the castle of Saumur. Many magnificent castles and cathedrals were constructed during the Middle Ages, using only simple tools and the great skill of the masons who cut and carved the stone.

The church was the center of village life

Doves and pigeons were kept for meat in a "dovecote" tower

Haystack

Beehives provided honey to sweeten food and make medicines

The farmer had to give one-tenth, or tithe, of all he produced to the local priest

FARMHOUSE

This painting shows life on a farm in winter. Farmhouses were usually simple buildings with just one or two rooms where everyone would eat, sleep, and live together. The windows were small and did not have glass, which was very expensive.

MEDIEVAL LIFE

Medieval means "middle age" and is the name given to the period of European history between the fall of the Roman Empire, in the 5th century, and the beginning of modern history, around 1500. During the Middle Ages, 90 percent of the population lived in the countryside as peasants–poor laborers who worked for wealthy nobles.

BOOK OF HOURS

These paintings are taken from a prayer book called "Book of Hours." It was made for the French Duke of Berry around 1410 and details prayers to say at different times of the day and year. In the Middle Ages, books were rare and precious objects, handwritten and illustrated by monks, and most were religious texts.

AMERICAN CIVILIZATIONS

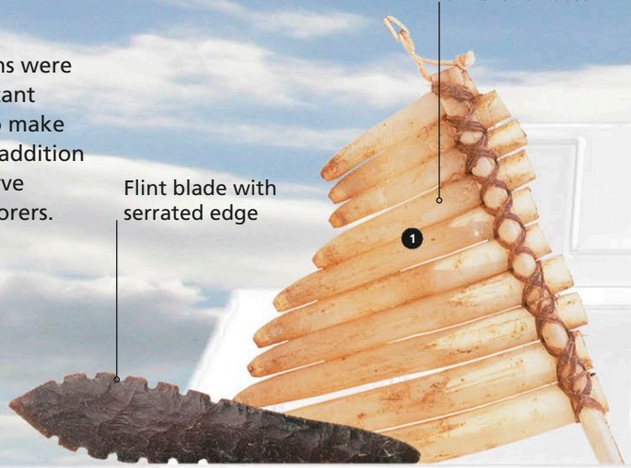
Until the arrival of European invaders in the 16th century, complex and powerful civilizations flourished in the Americas. From 250 to 900 CE, the Mayan kingdoms of Central America built cities with huge stone temples and developed systems of mathematics and astronomy. From the 14th century, the mighty Aztec Empire built pyramid temples and made sacrifices to their sun god. In the 15th century, the Inca Empire stretched for more than 2,000 miles (3,200 km) along the Pacific coast of South America, with a network of roads and fortress cities high in the Andes Mountains.

❶ EVERYDAY LIFE

The Aztec, Inca, and Mayan civilizations were all based on farming. The most important food crop was maize (or corn), used to make pancakes, called tortillas, and beer. In addition to farming the land, people had to serve their rulers as soldiers, builders, or laborers.

❷ POTTERY

American people made pots by rolling clay into long strips, which they coiled to make the walls of their vessels.Pottery served both a practical purpose, such as carrying liquids and boiling food, and a decorative one.

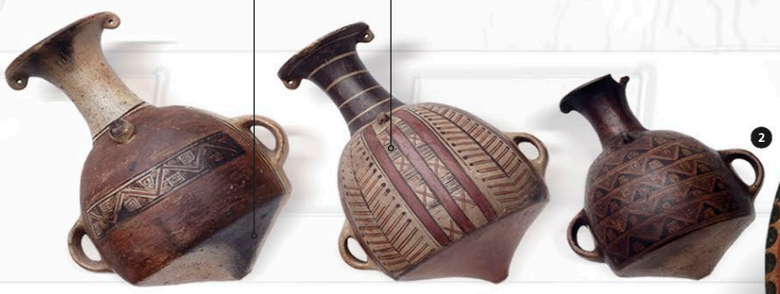


Knife There were no metal tools, so knives were made of stone.

Music The Incas made music by blowing across the top of cane pipes.

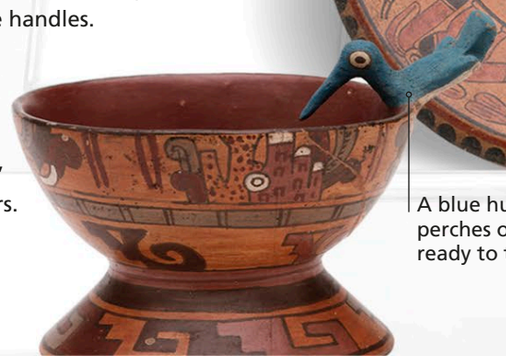
Drink The Incas drank "chicha" (maize beer) from painted wooden beakers.

Rain god Chac, the Mayan rain god, had a long nose and fangs.



Inca pots The Incas used these pots to carry and store beer. People carried them on their backs, using a rope passed between the handles.

Plate Paintings on pots often reveal details of daily life. This Mayan plate shows how people hunted deer using blowpipes.



Mixtec cup This cup was made by the Mixtecs, the Aztecs' southern neighbors.

❸ GODS

The Aztecs and Mayans worshiped many gods and goddesses, whose statues they kept in pyramid temples. They believed that the gods made the sun rise in the morning, the rain fall, and the crops grow. For the Incas, the sun, moon and Earth were themselves gods. Inti, the sun god, was the most important of them.

❹ KEEPING RECORDS

These civilizations had various ways of keeping records. The Aztecs used a picture writing system, with pictures standing for words and ideas. The Maya had a more complex system, with signs standing for sounds. The Incas did not write but kept records using lengths of knotted string, called quipus.

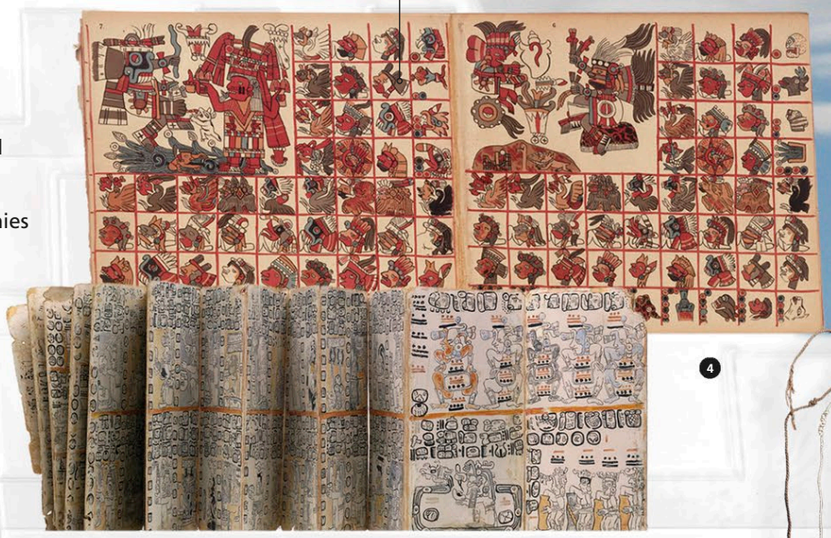
❺ RITUALS

People believed that the gods needed to be given offerings to ensure their continued goodwill. The most precious offering was human life, and the Aztecs, Maya, and Incas all practiced human sacrifice. The Aztecs and Maya went to war to capture prisoners, whose hearts were offered to the gods.

Chac carries a ball of incense, which was burned at religious ceremonies

Gold was the "sweat of the sun" to the Incas

Offering Gold figurines were left by the Incas as offerings to the sun and Earth.



Aztec signs for different days

Mayan records Mayan books were painted on paper made from fig tree bark, which folded up like an accordion.

Calendar This book is a calendar, used by Aztec priests to predict the future.

Quipu The color, size, number, and position of the knots all had a significance to the Incas.

Knots were used for counting

Shield Aztec warriors wore colorful costumes and carried shields decorated with feathers.

Tezcatlipoca, an Aztec god of war and strife

Funerary urn Burned bones of Aztec warriors who died in battle were buried in urns.

This mask is from Teotihuacán—an earlier civilization than the Aztecs

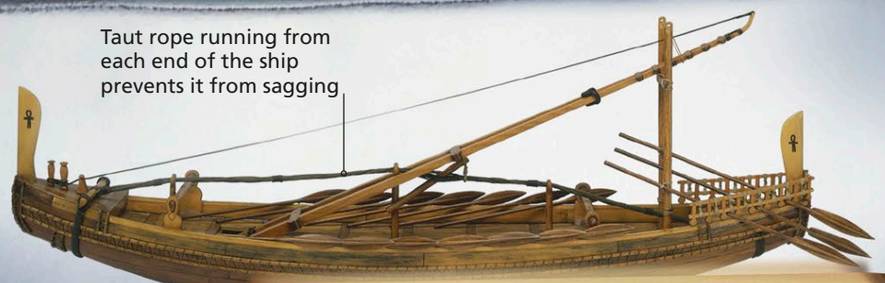
Stone mask Carved stone masks were placed as offerings in Mexican temples.

Eye shapes were often part of the knife's decoration

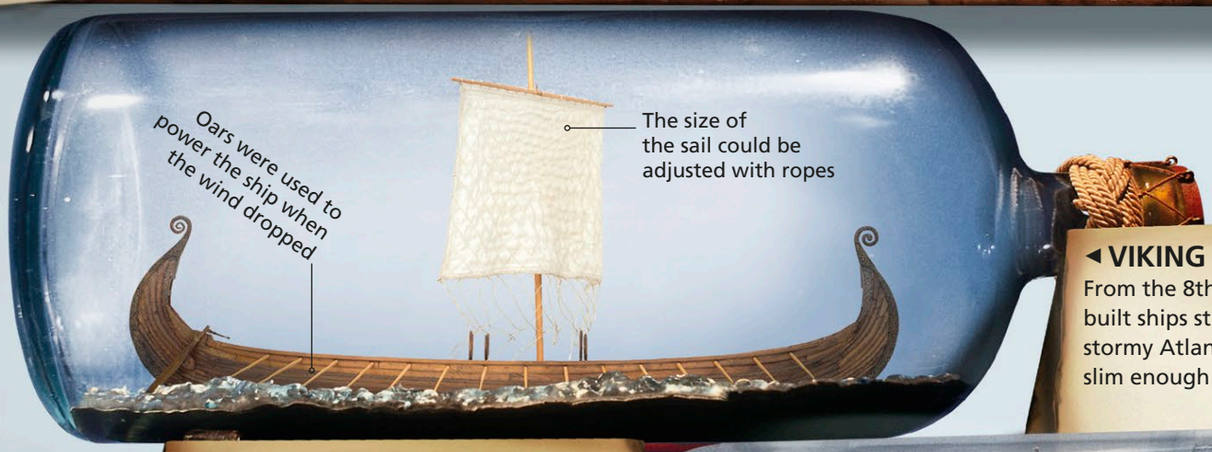
Sacrificial knife Aztec priests used stone knives to cut out the hearts of prisoners of war.

SEAFARERS

Seagoing craft have been built for at least 50,000 years. The first boats were probably log rafts or hollowed out tree trunks. At some point, people came up with the idea of catching the wind by raising a piece of cloth–the first sail. As ship building methods improved, sailors set off on longer voyages, using their ships to explore, to trade, and to raid.

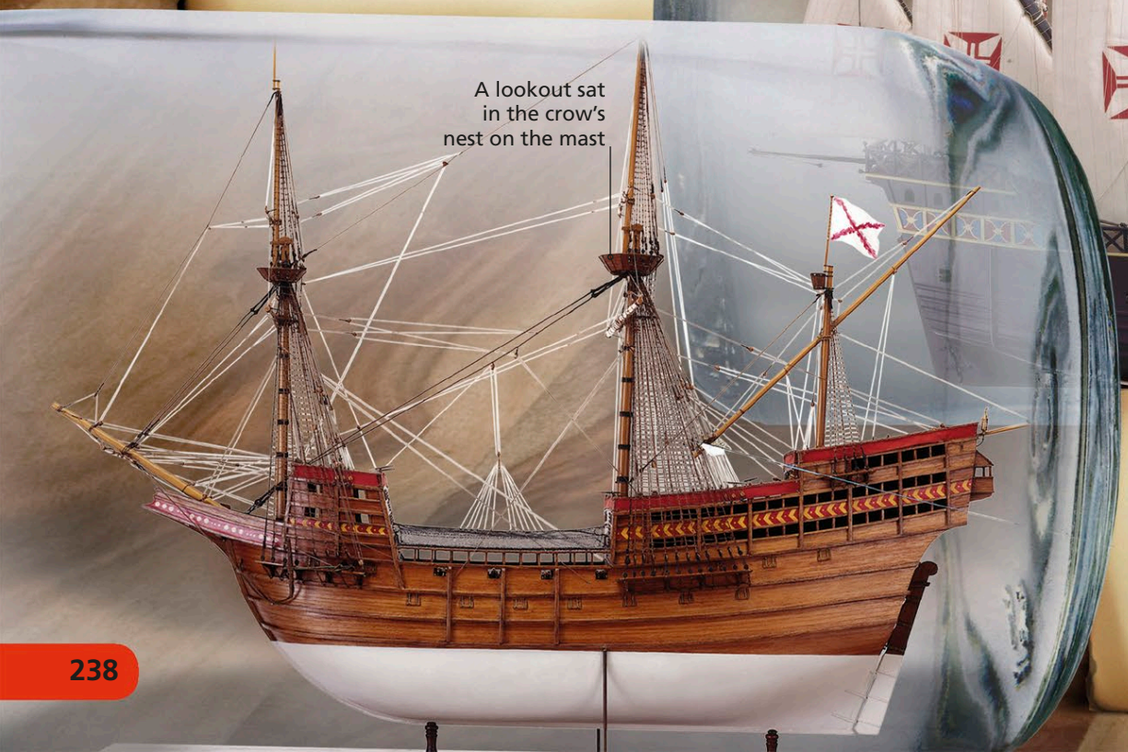


EGYPTIAN SHIP ▲
This Egyptian seagoing merchant ship is constructed from planks tied together with rope and dates from 2,450 BCE. Its collapsible mast carried a single square sail. Traveling against the wind, the crew lowered the mast and used oars.



◄ VIKING LONGSHIP
From the 8th to 11th centuries, Vikings built ships strong enough to sail the stormy Atlantic Ocean and light and slim enough to travel up shallow rivers.

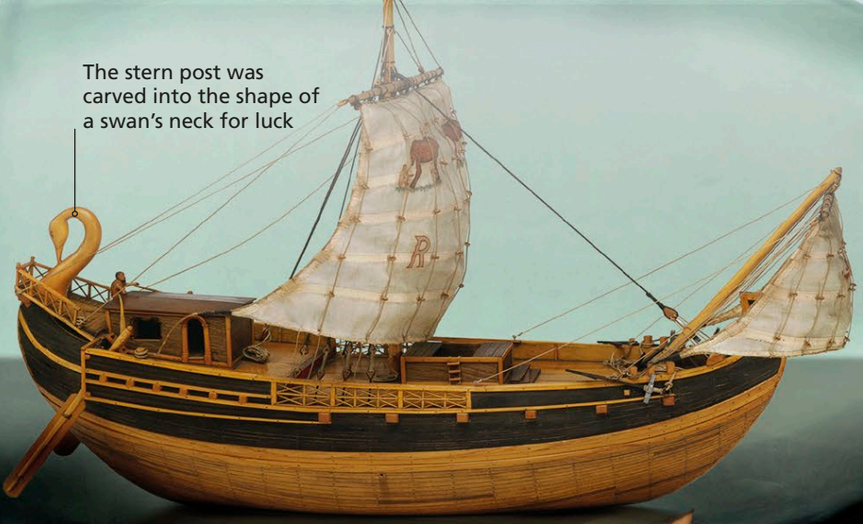
CARAVEL ►
The caravel was a ship for exploration, invented by the Portuguese in the 15th century. It had lateen (triangular) sails, which are much better at sailing into the wind than square sails. In ships like this, explorers found the sea route to India.



◄ GALLEON
This 16th-century English galleon warship was also used in trading and exploration. It had several decks, with many openings in the sides of the hull from which guns were fired. European navies used the galleon until the 18th century.

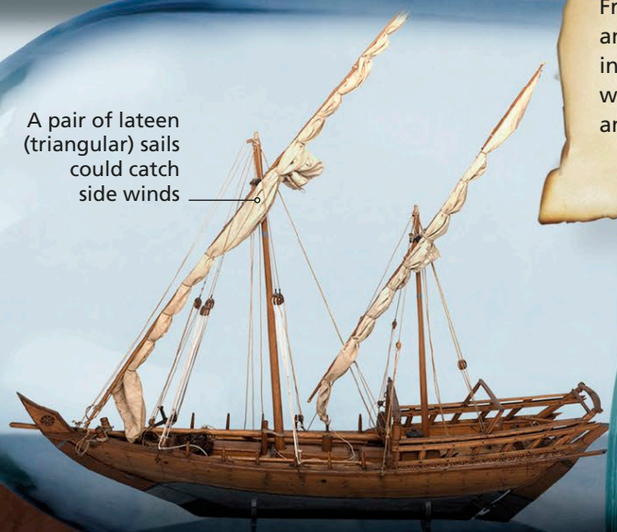
ROMAN MERCHANT SHIP ►

The Romans built merchant ships with big, round bellies that could store large amounts of cargo. This shape made them stable but very slow. They were usually safe from attack, because the Romans had rid the Mediterranean Sea of pirates.



◄ ARAB DHOW

From the 8th century, Arab merchants and fishermen crossed the Indian Ocean in dhows. They sailed with the monsoon winds, trading goods between India and North Africa.



CHINESE JUNK ►

The stern-mounted rudder, easier to control than a steering oar, was invented by the Chinese, 2,000 years ago. Chinese ships, called junks, could have up to nine masts and were the largest wooden sailing ships in history.

CLIPPER ►

The clipper was a 19th-century trading ship with a long, slim hull and multiple sails. The name "clipper" was originally a nickname for a fast horse. British and US clippers sailed all around the world on trading journeys.

WAR

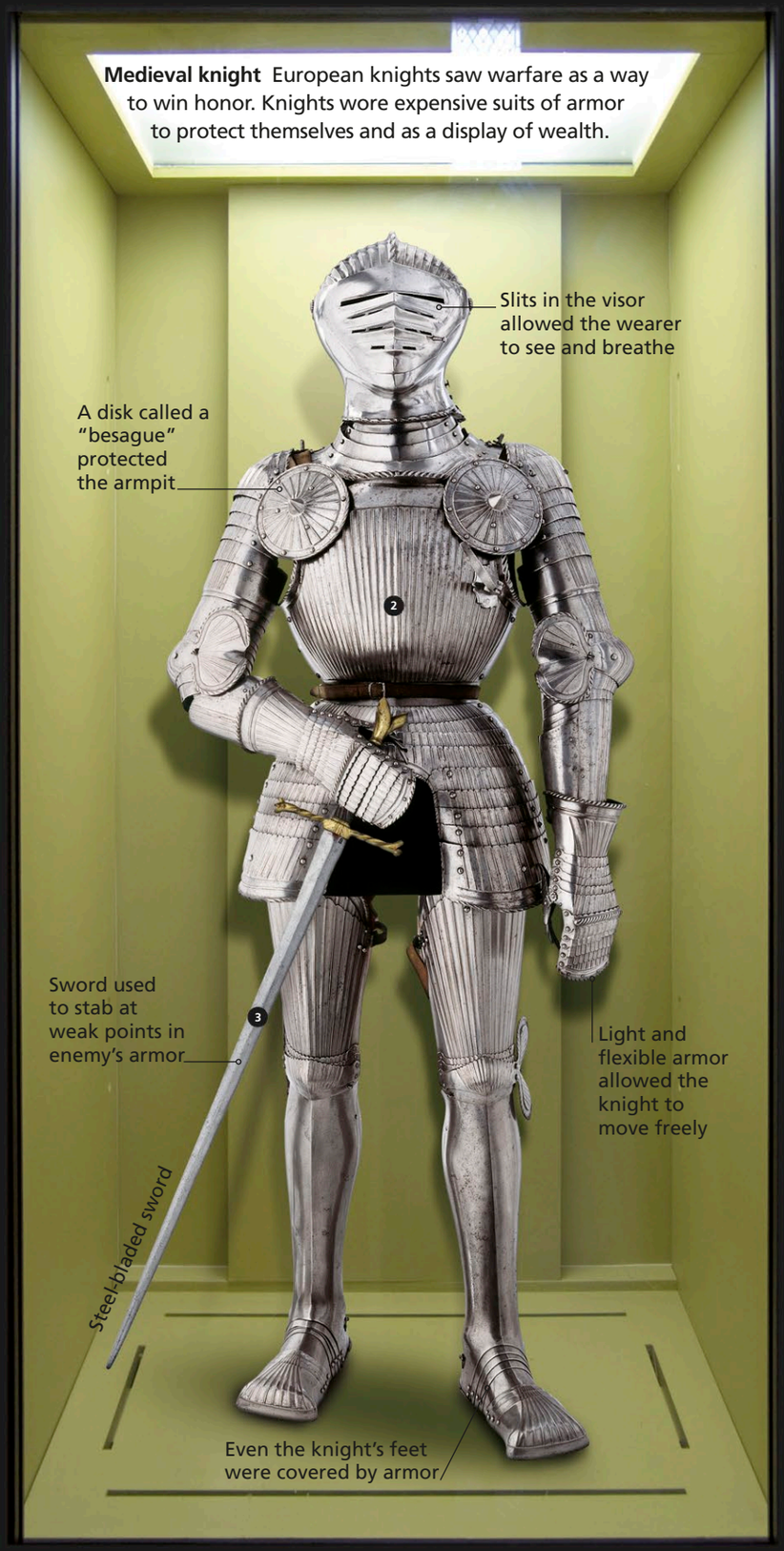
Throughout history, wars have broken out between tribes or nations over land, resources, and status. Methods of fighting changed over time, as people invented new, deadly weapons to fight with and improved ways of protecting soldiers from injury in battle.

❶ BOW AND ARROW

The bow and arrow, invented more than 12,000 years ago, is one of the oldest weapons used in war. There are various types. The longbow was often used by foot soldiers, while this short Mongol bow is designed to be used from horseback.

❷ ARMOR

The earliest soldiers wore armor made from wood, leather, and bone. After people discovered how to work metals, soldiers could wear armor made of mail (interlocking metal rings) or metal plates.



❸ SWORD

Swords are weapons for close combat (hand-to-hand fighting). They have a point for stabbing and one or two sharp edges for slashing. A crossguard above the hilt (handle) prevents the user's hand from sliding down onto the blade and protects it from an enemy's sword.

❹ UNIFORM

In the confusion of battle, soldiers need to be able to tell friend from foe. Uniforms mark out which side a soldier belongs to and encourage discipline—soldiers wearing identical uniforms are more likely to act together as a group.

❺ FIREARMS

Invented in China in the 14th century, firearms (portable guns) increased a soldier's ability to kill his enemy from a distance. These weapons ended the age of the knight, whose expensive armor could offer little protection.

❻ CAMOUFLAGE

In the 20th century, brightly colored uniforms were replaced by clothes that helped soldiers blend in with their surroundings. Colors and patterns like the green and black stripes on this uniform are known as camouflage, from the French *camoufler* (to disguise).

REVOLUTIONS

A revolution is a sweeping social change that takes place in a short period of time. This is often violent, as unpopular governments are overthrown, either by mass uprisings or small groups of organized revolutionaries. The goal of revolutionaries is to create a better society–to make people more equal, or more free. Yet it is often easier to destroy a bad government than it is to create a better one.

▼ REVOLUTIONARY WAR

Between 1775–1781, Britain's 13 colonies in North America fought a war of independence, in which they successfully threw off the rule of King George III. In their 1776 Declaration of Independence (below), the American leaders declared that "all men are created equal" with the right to "life, liberty, and the pursuit of happiness."

IN CONGRESS, JULY 4, 1776.

The unanimous Declaration of the thirteen united States of America,

▲ FRENCH REVOLUTION

In 1789, rioting against the government of King Louis XVI spread across France. Using the slogan of "liberty, equality, fraternity," revolutionaries overthrew the king. In 1793, the French leaders launched a reign of terror, during which they executed all opponents, including the king, by guillotine.

◄ **RUSSIAN REVOLUTION**
The Bolshevik Party, led by Vladimir Lenin, seized power in Russia in October 1917 and founded the first communist state. The communists set about creating a new kind of society, a "workers' state" based on common ownership of industry and land.

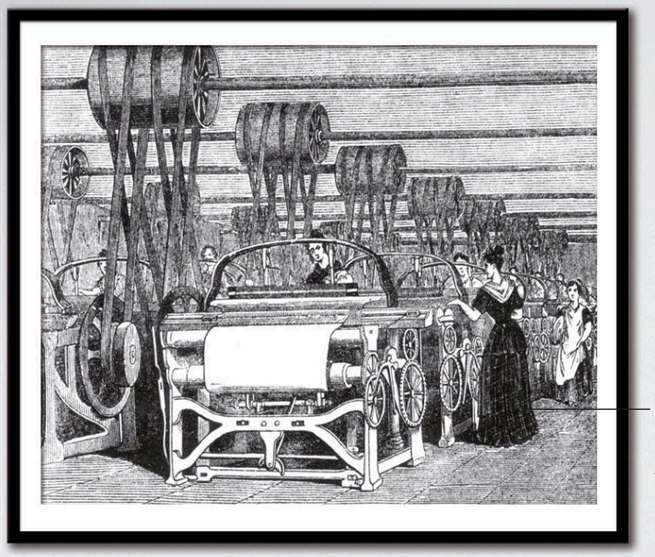
◄ **CUBAN REVOLUTION**
In 1956–1959, Cuban rebels, led by Fidel Castro and Che Guevara (left), overthrew the corrupt government of the dictator, Fulgencio Batista. Although Castro went on to rule as another dictator, he improved conditions for the Cuban poor and provided them with greater access to hospitals and schools.

▼ **CULTURAL REVOLUTION**
In 1949, communists, led by Mao Zedong, took power in China. In 1966, Mao, who feared that China was sliding away from communist principles, launched a "cultural revolution" to root out old ways of thinking. Opponents and intellectuals were persecuted, and the country came close to chaos.

▲ **VELVET REVOLUTION**
Mass protests in November 1989, and a general strike in Czechoslovakia, proved enough to bring down the unpopular communist government. The lack of violence led to this being called the "velvet," or soft, revolution. Here, marchers carry the flag of the new Czech Republic (Czechia).

INDUSTRIAL REVOLUTION

From the late 18th century, the invention of machines that could do things faster than ever before brought dramatic changes in the way people lived and worked. Known as the Industrial Revolution, these changes took root in Britain and quickly spread to Europe and the US. It began in the textile industry, with new machines powered first by water and later by steam. This led to a huge demand for coal, to fuel the engines, and iron, to make the machines. New towns sprang up as farm laborers moved from the countryside to work in the factories.



Factory workers endured hot, humid conditions and air thick with cotton dust

◄ FACTORIES

Huge buildings, called factories, were constructed to house the new machines, row upon row. Machines, such as these looms for weaving cotton into cloth, were powered by a steam engine, and the noise they made would have been deafening.

RAILROADS ►

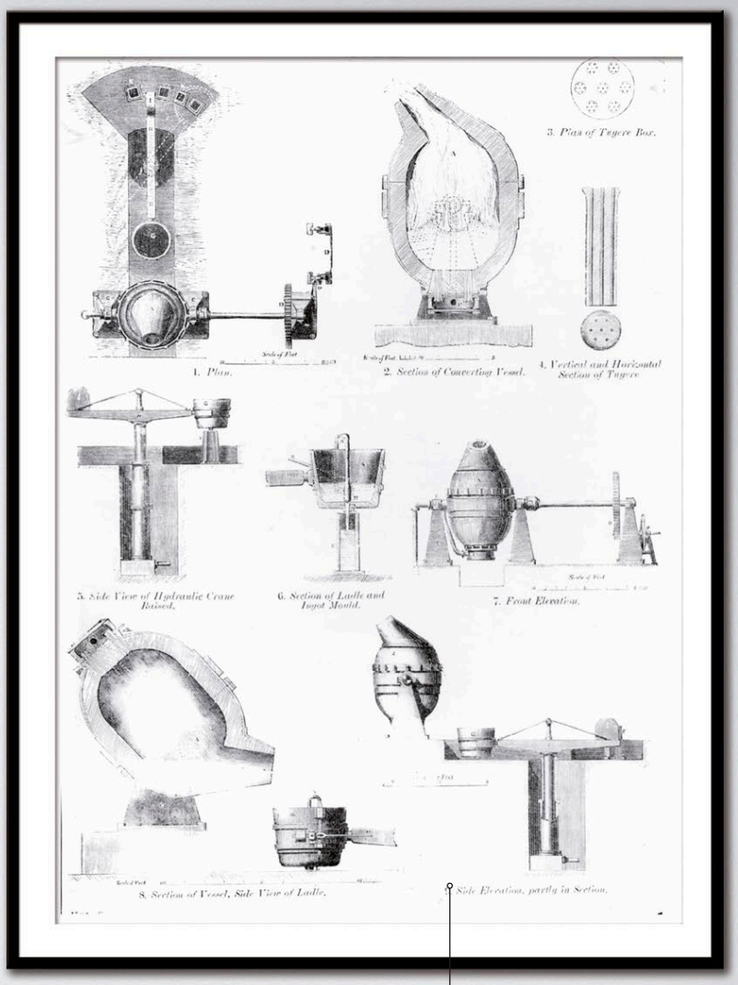
In 1804, British inventor Richard Trevithick built the first steam-powered locomotive. Early locomotives carried coal from mines. From 1825, passenger trains were built, and armies of workers lay down railway lines.

FACTORY WEAR ►

Factory owners preferred to hire women and children to men, because they were cheaper and easier to discipline. Women in the factories wore heavy, durable clothes, which were products themselves of the Industrial Revolution's textile boom.

"Puffing Billy," built in 1813–1814, is the world's oldest surviving steam locomotive

▲ **NEW TOWNS**
In the factory areas, villages grew into huge towns almost overnight. Workers' houses were built as cheaply as possible and often crammed closely together. The industrial towns were dark places, where the air was filled with smoke from the factory chimneys.



Plans for a new method of converting iron into steel, invented by Henry Bessemer in 1855

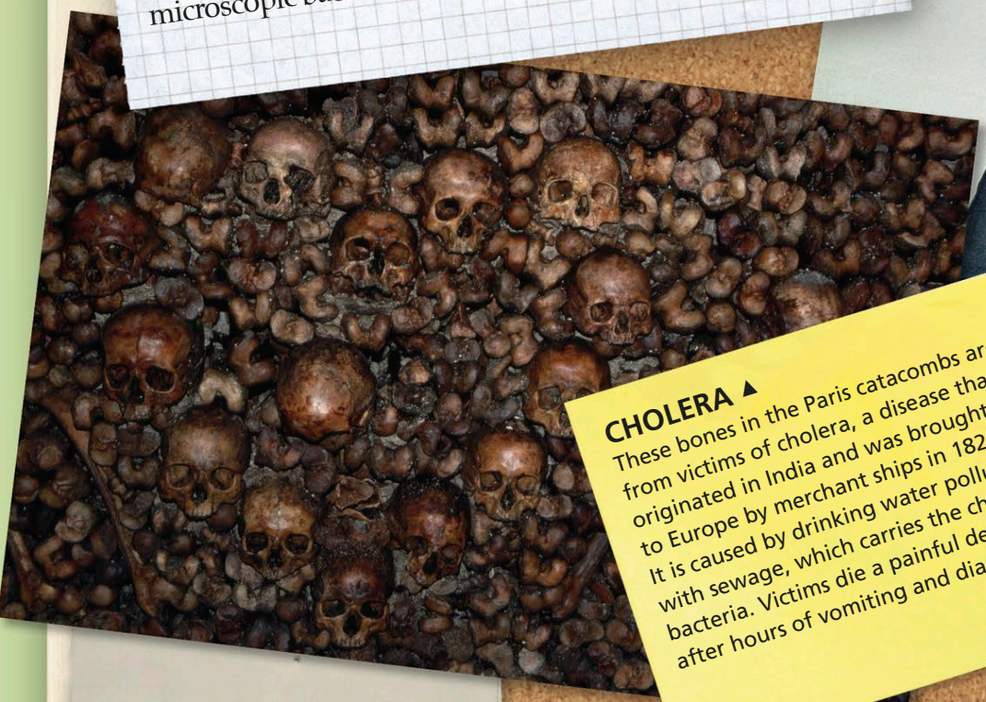
▲ **INVENTIONS**
The driving force of the Industrial Revolution was the rapid development of new ideas, methods, and machinery. Newly invented steam engines were used to power innovative new machines that transformed the mining, textiles, and metalworking industries.

▼ **DISEASE**
People lived crowded together in the new factory towns. They had no proper sewers, garbage collection, or clean drinking water. Diseases like cholera, typhus, and typhoid often swept through the towns, killing thousands.

Medicine box used to treat cholera

DISEASE

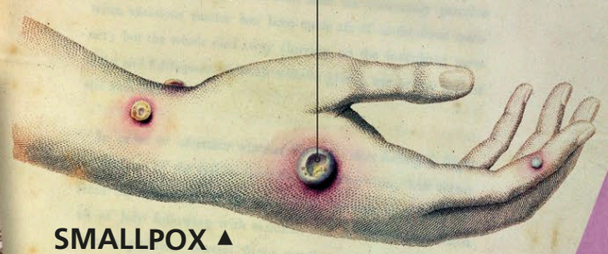
Wherever people have lived together in large numbers, diseases have spread. As ships traveled around the world, diseases like bubonic plague, the flu, and cholera spread from country to country. In the past, treatment was often ineffective since people did not understand the true causes of these diseases. We now know that they are caused by microscopic bacteria and viruses.



Some doctors wore birdlike masks stuffed with herbs believed to ward off the plague

◄ BUBONIC PLAGUE
In the 1340s, bubonic plague killed around half of the population of Europe, and millions more in Asia and Africa. People believed that they could catch the plague by breathing bad air. The true cause was bacteria, passed on by flea bites.

CHOLERA ▲
These bones in the Paris catacombs are from victims of cholera, a disease that originated in India and was brought to Europe by merchant ships in 1829. It is caused by drinking water polluted with sewage, which carries the cholera bacteria. Victims die a painful death, after hours of vomiting and diarrhea.



Smallpox caused painful raised blisters, which left scars behind after they healed

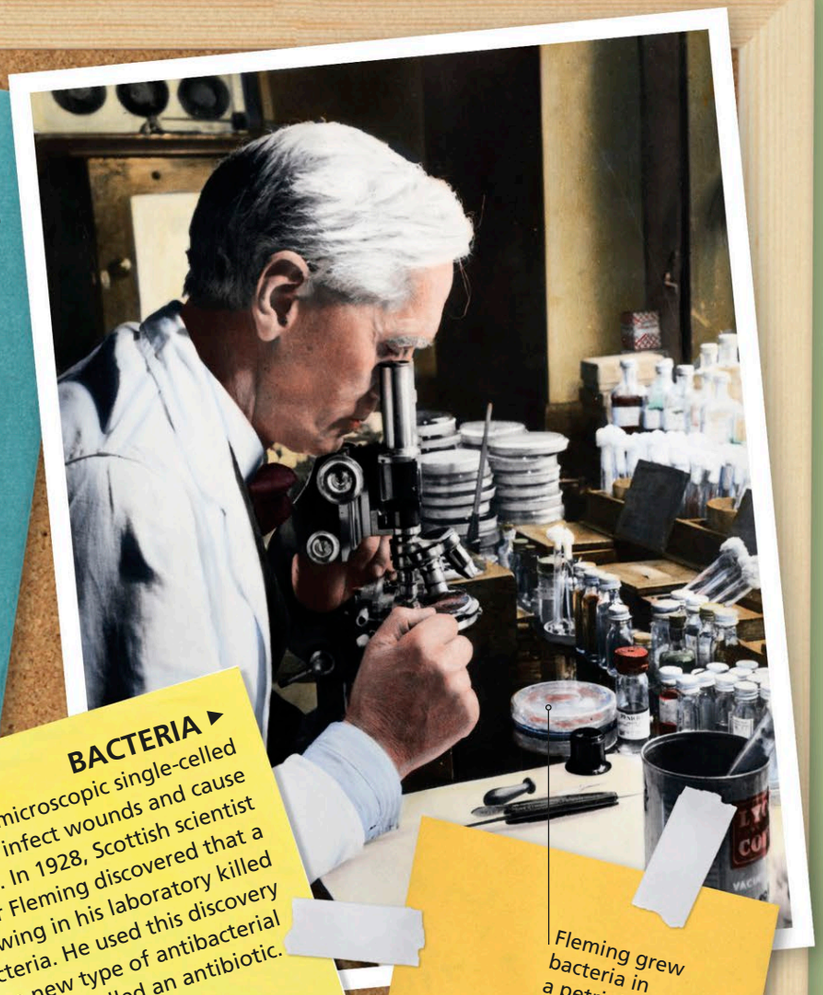
SMALLPOX ▲
Smallpox was a disease that could scar, blind, and even kill its victims. Like the flu or the common cold, it was caused by a virus, a minute agent that can grow or reproduce only inside the cells of living things. Smallpox is one disease that has been wiped out by modern medicine.

FLU PANDEMIC ►
A widespread outbreak of disease is called a pandemic. The worst case in history took place in 1918–1920, when a deadly strain of flu spread around the globe, killing 50–100 million people. Face masks were widely worn, for it was correctly understood that flu is spread by coughs and sneezes.

A nurse washes her hands in disinfectant in a 19th-century advertisement

◀ HYGIENE

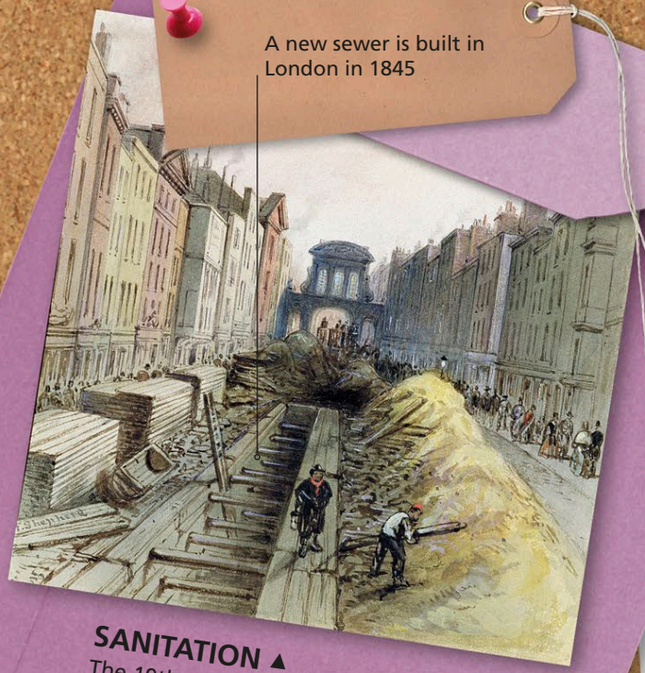
Until the 1860s, people did not understand the importance of hygiene in preventing infections. Surgeons did not even wash their hands before operating. In 1865, an English surgeon named Joseph Lister began to clean the wounds of his patients with carbolic acid. This killed the bacteria that infected the wounds.



Fleming grew bacteria in a petri dish

BACTERIA ▶

Bacteria are microscopic single-celled organisms that infect wounds and cause diseases. In 1928, Scottish scientist Alexander Fleming discovered that a mold growing in his laboratory killed harmful bacteria. He used this discovery to create a new type of antibacterial medicine, called an antibiotic.



A new sewer is built in London in 1845

SANITATION ▲

The 19th century saw several cholera pandemics in Europe. These were eventually ended by building proper sewers, which stopped bacteria from polluting drinking water. The last European pandemic took place in Russia in 1923. Cholera is still a problem in Asia and Africa, with an outbreak in Yemen in 2016.

◀ VACCINATION

A vaccine is a weak form of a disease that helps the body fight a more serious disease. English doctor Edward Jenner realized that people who caught cowpox (a mild form of smallpox) did not get the deadlier disease. In 1796, he injected eight-year-old James Phipps with pus from a cowpox blister. When he later tried to infect the boy with smallpox, James did not catch the disease, and the first vaccine had been created.

MONEY

Before money existed, people traded by bartering, or swapping, different goods. The problem with bartering was that each trader had to want what the other trader was selling. Money was invented as a medium of exchange–something with a recognized value that could be used to buy other goods. Money is usually made of rare materials, such as precious metals or colorful feathers.The first written records of money date back to Mesopotamia (now in southern Iraq) where weighed silver was used about 4,500 years ago.

Gold doubloons made by the Spanish invaders of Central America

Tobacco leaves were the currency for the British settlers in North America in the 17th and 18th centuries

At different times in history, cowrie shells have been used as payment in China, India, and Africa

Up until the 17th century, silver rings were the method of payment in Thailand

❶ EGYPTIAN HOARD
In Ancient Egypt, payments were made with various metals, and their value was based on weight not shape. This resulted in a wide array of bars, rings, and pieces of gold, silver, and copper.

❷ BURMESE WEIGHTS
During the 18th century, silver weights called "flower silvers" were used as money in Burma (now Myanmar). Liquid silver was poured into a mold, and a floral pattern added.

❸ TRADER'S MANUAL
Coins were regularly shipped overseas in the 16th century. To identify the different coins and their value, Dutch merchants used handbooks detailing foreign currency.

❹ FEATHER MONEY
The Pacific Islanders of Santa Cruz used long coils made of feathers to buy canoes. The brightest and boldest feathers had the highest value.

❺ CHINESE COINS
In 500 BCE, bronze coins in China were made to resemble tools or the cowrie shells of an earlier currency. The shapes were so awkward, they were replaced by circular coins with square holes.

❻ BANK NOTE
Paper money has its origins in 10th-century China. Handwritten receipts provided by merchants gained such importance that the government started printing paper receipts for specific sums.

❼ WAMPUM
Native Americans created belts known as wampum from white and purple clam shells. These belts represented money and were used to seal deals.

❽ STONE MONEY
Heavy currency was used by the islanders of Yap in the Pacific Ocean. The huge stone disks they used to pay for items were often too weighty to lift, some measuring 13 ft (4 m) across.

❾ CHECK
An alternative to cash is a check—a form that details how much money should be transferred from one bank account to another. In medieval times, the Knights Templar issued checks to pilgrims so they could travel across Europe without carrying money.

❿ CREDIT CARDS
First used in 1920s America to buy gas, many people now rely on plastic credit cards. Issued by banks and businesses, cards are a convenient alternative to cash.

❸

Shells stored in wicker container
Red feathers were woven into rolls
This bank note from Rome was issued in 1786
Japanese ingot coins in the 17th century were hammered gold or silver bars
Embedded microchip acts as a computer
BANCO DI S. SPIRITO DI ROMA
CREDIT CARD
DEBIT CARD
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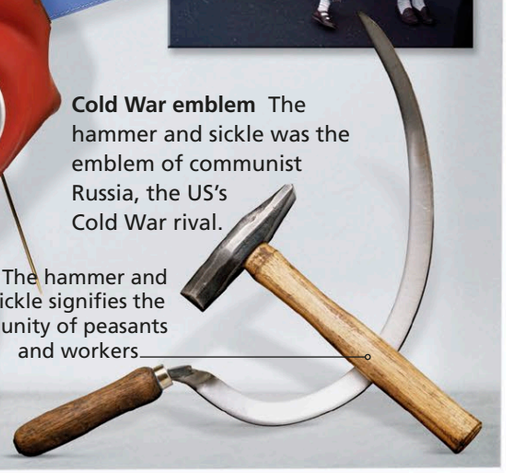
20TH CENTURY

The 20th century saw more changes in the way people lived their lives than any other century. Among the century's many new inventions were television, computers, the Internet, and nuclear power. The century began with the first airplane flight, lasting just 12 seconds, in 1903. By 1969, US astronauts had flown to the moon and walked on its surface.

Protests The 1960s saw many people march in antiwar protests.

UN The United Nations (UN) is an international organization that was set up in 1945 to help prevent wars.



CONFLICTS

World War I (1914–1918) left 20 million dead, mostly young soldiers. Military air power during World War II (1939–1945) made cities vulnerable to attack. Around 60 million people died, many of them civilians. This was followed by the Cold War, a long standoff between the US and communist Russia.

Gas masks These were issued to soldiers in World War I and to both soldiers and civilians in World War II.

Cold War emblem The hammer and sickle was the emblem of communist Russia, the US's Cold War rival.

The hammer and sickle signifies the unity of peasants and workers.

Refrigerator Mass production of home refrigerators began after World War II.

ENTERTAINMENT

Radios were invented at the beginning of the century, and the 1920s saw the arrival of radio broadcasts. In the 1930s and 1940s, going to the movies was the most popular leisure activity. In the 1950s and 1960s, the popularity of movie theaters waned, as people stayed at home to watch the new invention, television.

Walkman In the 1980s, the personal cassette player let people listen to music on the move.

Gramophone The first record players were powered by turning a handle at the side.

Television Early televisions were small and showed only grainy black-and-white pictures.

Radio In the early part of the century, the whole family would sit around listening to the radio.

Movies People flocked to movie theaters to watch their Hollywood idols.

AIDS From the 1980s onward, a terrible new disease called AIDS claimed the lives of millions of people around the world.

Famine Many countries faced humanitarian crises.

DOMESTIC LIFE

Many new labor-saving devices were invented for the home, including refrigerators, freezers, washing machines, dishwashers, and vacuum cleaners. The ability to prevent food from decaying by freezing it enabled food to be transported greater distances and allowed people to buy and store it in bulk. Shortly after, precooked frozen meals emerged, changing mealtimes forever.

TV dinner Prepackaged meals could be heated then eaten while watching television.

TRAVEL

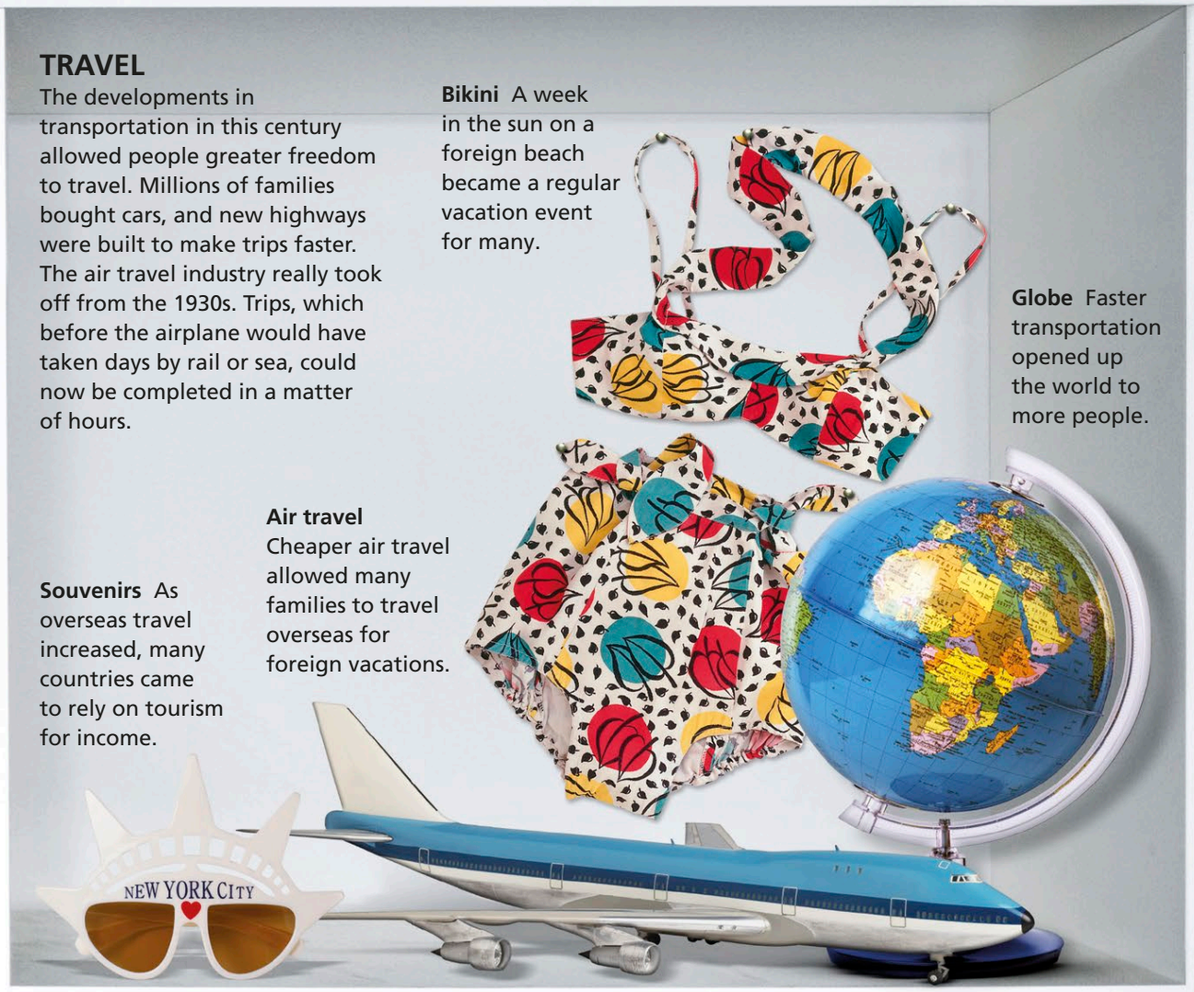
The developments in transportation in this century allowed people greater freedom to travel. Millions of families bought cars, and new highways were built to make trips faster. The air travel industry really took off from the 1930s. Trips, which before the airplane would have taken days by rail or sea, could now be completed in a matter of hours.

Bikini A week in the sun on a foreign beach became a regular vacation event for many.

Globe Faster transportation opened up the world to more people.

Air travel Cheaper air travel allowed many families to travel overseas for foreign vacations.

Souvenirs As overseas travel increased, many countries came to rely on tourism for income.



Apartheid Nelson Mandela led the successful struggle to win equal rights for black South Africans.

ISSUES

The world's population rose from 1.65 to 6 billion people during the century, with a widening gap between rich and poor nations. There was inequality between men and women and people of different races.

Votes This medal was given to a female hunger striker campaigning for the vote for women.

WORK

The role of women in the workplace greatly changed during the century. Women had limited career options in the early decades but gained more employment rights and opportunities as the century progressed. The workplace was also transformed by new methods of communication, including the computer and Internet. New technologies led to automated factories, reducing the need for manual labor.

Women in the workplace In the 1970s, women fought for the right to the same work opportunities and pay as men.

Computer technology From the late 1970s, personal computers began to revolutionize the workplace.

Typewriter For much of the century, office workers used typewriters to write documents.

Telephone Improved communication technology enabled businesses to go global.

PICTURE GALLERY
David Teniers's 1651 painting *Archduke Leopold Wilhelm in his Picture Gallery* features one of the greatest art collections of the age, which numbered 1,300 works. The archduke governed Southern Netherlands (Belgium).

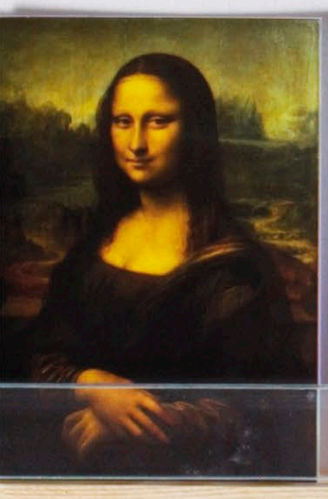
Art and culture

ART

Some artists seek to create a beautiful object; others use art to reveal something about the world. In the past, art also served a religious, magical, or mystical purpose. Styles of art vary widely, and artists from different cultures have shown the human form in many different ways.

The first art This carving of a pregnant woman, found in Austria, was made 25,000 years ago. Her hair is shown in detail, yet she has no facial features.

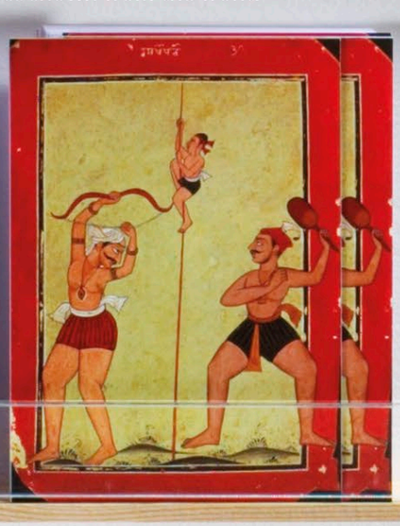
Tomb art Egyptian painters showed each part of the body from its most distinctive angle. Heads and limbs were viewed from the sides, with eyes and torsos shown from the front.



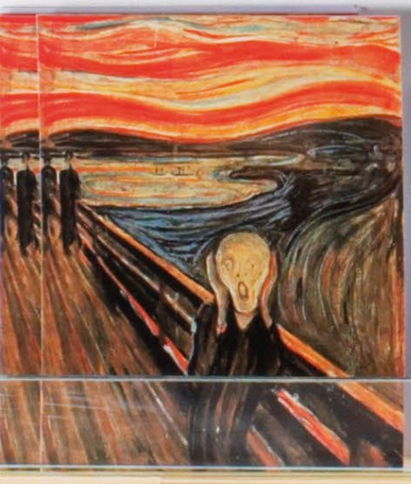
Mona Lisa With her mysterious half smile, this is the world's most famous work of art. It was painted in 1503–1507 by Italian artist Leonardo da Vinci.

Royal portrait German artist, Hans Holbein, was court painter to Henry VIII of England. His 1539 portrait of Henry's son, Edward, shows the clothing in great detail.

Self-portrait Dutch artist Rembrandt van Rijn (1606–1669) painted 60 self-portraits to experiment with techniques and to document his life.



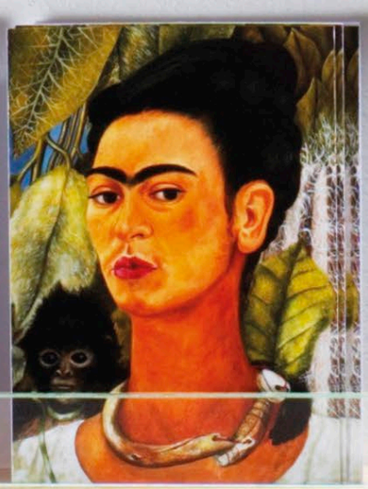
Indian art This painting, made in 1770, is not a realistic image but follows set rules. The athletes' heads are shown in profile while their chests face out.



Emotion art In *The Scream* (1893), Norwegian Edvard Munch aimed to express emotion rather than depict a real scene.

New forms Spanish artist Pablo Picasso (1881–1973) took the human form apart and reassembled it in startling ways.

Art Deco Polish artist Tamara de Lempicka (1898–1980) belonged to the Art Deco movement, which saw art as purely decorative.



Self-image Mexican artist, Frida Kahlo (1907–1954), painted self-portraits using scenes drawn from fantasy.

Terra-cotta Army In 209 BCE, more than 8,000 life-sized pottery figures of soldiers were buried to guard the tomb of China's first emperor. Every soldier has different features.

Prayer book Medieval European art often served a religious purpose. This illustrated book depicts the Virgin Mary holding the baby Jesus.

African mask These elaborate works of art were worn for ritual dances, when the wearer communicated with spirits.

Japanese print In 1794, artist Toshusai Sharaku made this woodcut print of an actor named Otani Oniji. He is shown performing the role of a villain, grimacing threateningly.

Brush strokes Like Rembrandt, Dutch artist, Vincent Van Gogh (1853–1890), painted many self-portraits, 30 of them in the last five years of his life. He had a loose style, with each brush stroke visible.

Impressionism French artist Edgar Degas (1834–1917) founded an artistic movement called Impressionism. Its goal, shown in this painting of ballerinas, was to capture changing light and movement.

Sculptural curves Reducing human figures to simple curving shapes was a speciality of British sculptor Henry Moore (1898–1986).

Pop art Andy Warhol (1928–1987) used subjects drawn from popular culture. In 1962, Warhol used a photo of movie star Marilyn Monroe to make this screenprint.

Cartoon art US artist Keith Haring (1958–1990) started his career as a graffiti artist, drawing cartoonlike figures.

ARCHITECTURE

The art and science of designing buildings and other structures is known as architecture. From early times, people designed buildings both for practical reasons, such as shelters to live in, and religious reasons, such as stone tombs and places to worship the gods. Over the centuries, architecture has evolved to become an art form using high-quality materials to create ever more daring designs.

❶ THE COLOSSEUM
The first permanent amphitheater in Rome, the Colosseum was completed in 80 CE. It is amazing not only for its size but also for its design. Up to 50,000 spectators poured safely in and out of 80 doors to watch all-day gladiator battles and other public spectacles.

❷ HEDDAL STAVKIRKE
As 12th-century Norwegians turned away from Viking beliefs to follow Christianity, they built a thousand beautiful wooden stave churches along trade routes in Norway. Carvings of animals often decorated the door frames.

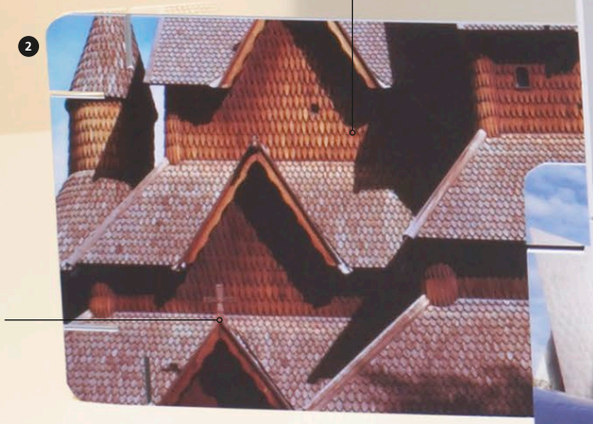
❸ KUNSTHAUS GRAZ
Nicknamed "the friendly alien" by locals, this Austrian art museum, completed in 2003, has a blue outer skin of acrylic glass that can display images and animations. Inside, two large spaces can be adapted to display different exhibitions.

❹ DISNEY CONCERT HALL
This striking home for the Los Angeles Philharmonic Orchestra took 16 years to complete from design to opening night in 2003. Its striking exterior is made of stainless steel curves. The wood-paneled main auditorium features state-of-the-art acoustics.

❺ CHRYSLER BUILDING
This 1920s skyscraper in New York City remains the tallest brick building in the world at 1,047 ft (319 m). It was designed to house the Chrysler automobile company, and the gargoyles that jut from the building were designed like car mascots.

❻ REICHSTAG
This building housed the German Republic parliament from 1894 until it burned down in 1933. When Germany reunited in 1990, the Bundestag (the new parliament) returned to Berlin. The original building was gutted and a new home built inside the old walls.

❼ DJENNÉ MOSQUE
The largest mud-brick building in the world, the present mosque in Mali dates from 1909. The thick walls are coated with a smooth layer of plasterlike mud to even out the surface. Palm-wood supports help people scale the walls to repair them each spring.



In 2005, some panels were sanded down after nearby residents complained about the glare and heat of reflected light

5 Triangular windows set in seven silvery arches under a spire crown the top of the building

8 BURJ KHALIFA

Designed to resemble a desert flower, *Hymenocallis*, this 2,717 ft (828 m) skyscraper in Dubai is the tallest building in the world. The Burj Khalifa has more than 160 stories and the world's highest outdoor observation deck. The structure is three times as tall as the Eiffel Tower in Paris.

9 EL PALAU DE LES ARTS

This Spanish opera house is part of a complex of museum buildings near Valencia. It is set within landscaped gardens with reflecting pools and interlinked paths. The roof is made from a pair of curving steel shells clad in concrete and mosaic tiles.

10 ALLIANZ ARENA

This soccer stadium is located in Munich, Germany, and is the only stadium in the world that can change its exterior color. Opened in 2005, the stadium holds nearly 70,000 spectators. Some locals nicknamed it the "inflatable boat" due to its unusual shape.

Visitors travel up a spiral walkway in the huge glass dome to take in a panoramic view of the Berlin skyline

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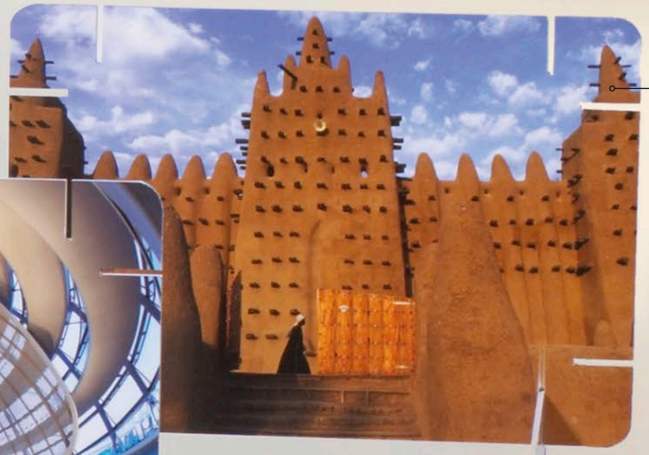


Three massive towers are topped with oval spires shaped like ostrich eggs, which symbolize purity

Some 3,000 air-filled foil panels that form the exterior can be lit from within to match the home team's colors

The opera house has been compared to an ocean liner, with its sleek exterior and shiplike decks inside

10

The cladding system on the building's exterior is designed to withstand Dubai's extreme heat

8

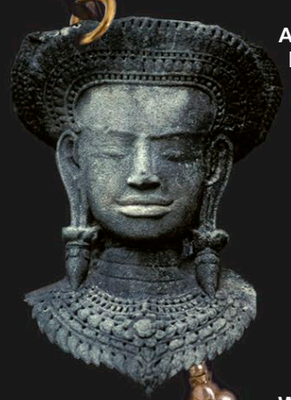
9

SYMBOLS

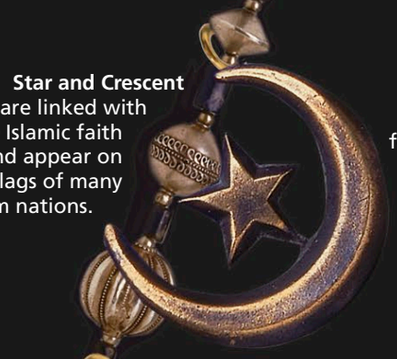
From a fire-breathing dragon to a four-leaf clover, people use symbols–images, objects, and figures–to represent abstract ideas or concepts. Symbols can best be described as something visible that represents something invisible. We use them every day without thinking about it. For example, our written language and numbers are made up of symbols.

RELIGION

Followers of different faiths can express religious concepts, such as their idea of God, through symbols. Religious symbols have many meanings and uses and may be used in places of worship or as part of other religious practices.



Apsaras This supernatural being represents the female spirit in Hindu mythology.

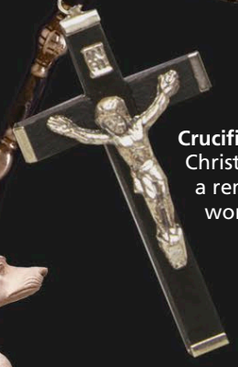


Star and Crescent These are linked with the Islamic faith and appear on the flags of many Muslim nations.

Yin Yang This symbol of the Taoist belief represents harmony and unity in the universe.

Wheel of Law The eight spokes of this Buddhist symbol represent the eight paths to enlightenment.

Star of David Named for King David of Israel, this has been a symbol of the Jewish faith since medieval times.



Crucifix This shows Jesus Christ's death on the cross—a reminder to Christian worshipers of his sacrfice.

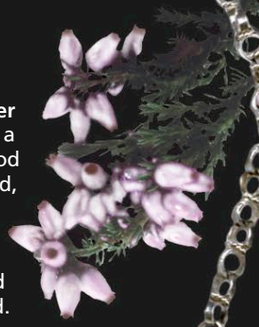
Anubis The Ancient Egyptian god of the dead, Anubis led the mummification process and protected the dead.

GOOD LUCK

People hoping to protect themselves from misfortune or evil may carry a good-luck symbol. It could be a trinket, a piece of jewelry, or something from nature. Many symbols are lucky only to a particular culture, and the superstition can stretch back centuries.

Fu Thought to bring good fortune, this Chinese symbol decorates envelopes given to children for Lunar New Year.

Saint Christoper Some Christians wear pendants showing the patron saint of long journeys to protect them when they travel.



White heather Regarded as a symbol of good luck in Scotland, some say heather grew on battlefields where no blood had been shed.

Four-leaf clover Most have three leaves, so superstition has it that finding one by accident brings good luck.

Horseshoe In Europe and the US, hanging a horsehoe by the front door will bring good fortune.

Evil eye This symbol is meant to block a curse sent by the nasty stare of an envious person.

MYTHICAL BEASTS

These creatures existed only in myths and legends, but they hold real symbolic meaning for many people. They may be created from parts of different animals or mixes between human and animal forms. Sometimes they can take the form of animals with incredible powers.

Salamander This creature is linked with fire and may represent the righteous who have escaped the flames of hell.

Centaur In Greek mythology, this half-man half-horse beast symbolizes the instinct of an animal with the judgment of a human.

Minotaur This ferocious creature from Greek mythology has the body of a man and the head of a bull. It is a symbol of conflict between reason and animal instincts.

Unicorn A horse with a twisted horn appears in the legends of many cultures. In China, it represents gentleness.

Makara An aquatic creature from Hindu mythology, makara is part fish, part crocodile. It symbolizes love.

Dragon This giant beast, which features strongly in Chinese mythology, is a symbol of power, said to be able to spit fire.

NATURE

In many cultures across the world, members of the animal kingdom are chosen as symbols of a particular quality people would like to have. When animals are used in this way, they are known as totems.

Eagle Seen as wise and majestic creatures, a cry from these usually silent birds is said to foretell a big event.

Snake Regarded as a symbol of evil in many cultures, it can also represent rebirth since it sheds its skin.

Owl A symbol of death in some parts of the world, in other cultures, owls are linked with wisdom.

Carp This fish is a symbol of strength in Japan and other parts of Asia, perhaps because it swims against the current of the river.

Dolphin These are seen as symbols of joy, love, and happiness.

Toad The Aztecs thought the toad was a powerful symbol of life and rebirth, while the Chinese associate them with wealth.

Beetle Amulets carved to resemble scarab beetles were the most powerful symbol in Ancient Egypt and were thought to give the wearer eternal life.

Monkey Three Japanese monkeys symbolize the principle "see no evil; hear no evil; speak no evil."

LANGUAGE

People communicate through language, whether the words are spoken or written down. Today, there are some 7,000 different languages spoken around the globe. Many more languages were spoken in the past, which have now been forgotten. The languages of the most powerful economic and political nations are spoken by millions of people.

❶ **Chinese** 1.3 billion people are native speakers of one of the family of Chinese languages. Some 880 million people communicate in Mandarin Chinese, a group of dialects (language variations) from northern and southwestern China.

❷ **French** Spoken by 220 million people worldwide, French is an official language of the United Nations. It is one of the family of Romance languages that developed from Latin.

❸ **Hebrew** The holy language of the Jewish faith, Hebrew is spoken by 9 million people around the world. Many religious texts are written in an ancient form of Hebrew, in use from the 12th to the 6th century BCE.

❹ **Arabic** Some 300 million people communicate with a dialect of Arabic, a family of very old languages closely related to Hebrew. The Quran, the holy book of the Islamic faith, is written in Arabic.

Written French has five accent marks to indicate pronunciation

The Hebrew alphabet uses 22 characters, written from right to left

Portuguese writing has 26 letters and five accent signs

Artists may use calligraphy (decorative writing) to write Arabic text in Islamic manuscripts

Japanese writing is often printed vertically

Around 4,000 characters are used in everyday written Chinese

In this Hindi script, symbols are joined together by a horizontal bar

In traditional written Spanish, 28 letters are used

In early Greek writing, there are no gaps between individual words

Many Bengali characters stand for a combined consonant and vowel sound

Latin is rarely spoken today, but its alphabet is the most widely used across the globe

Written Russian uses the Cyrillic alphabet, a medieval system named after its inventor, St. Cyril

The global use of English means that the language is constantly growing, with thousands of new words entering the language each year

❺ **Hindi** The family of languages spoken in northern and central India is known as Hindi. In addition to 425 million native speakers, there are many Indians who use Hindi as a second language.

❻ **Portuguese** This Romance language originated in Portugal but spread to parts of South America in the 16th and 17th centuries. Today, it has 230 million speakers worldwide.

❼ **Japanese** Used by 130 million people, the Japanese language can be adapted by the speaker to show respect to someone, according to their age and social status.

❽ **Spanish** Originating in northern Spain, this romance language has 577 million speakers. It is widely spoken in Central and Southern America. Today, Mexico has the most Spanish speakers.

❾ **Bengali** Also known as Bangla, this language is India's second most spoken language. Bengali is also used in other parts of southern Asia, with 230 million native speakers.

❿ **Greek** This ancient language has used the same alphabet since the 9th century BCE. Today, about 13 million speakers in Greece and Greek communities worldwide keep this language alive.

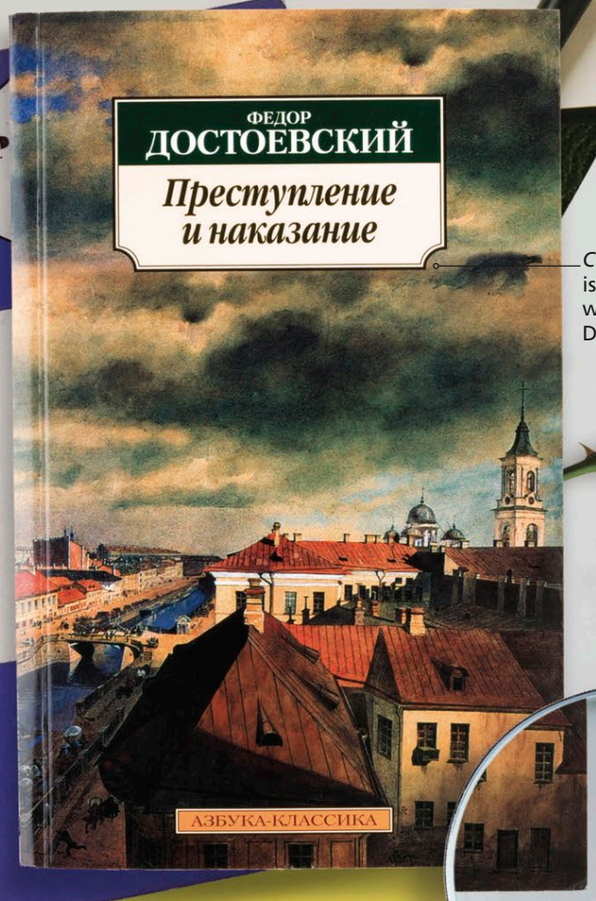
⓫ **Latin** The language of the Roman Empire, Latin developed into the family of Romance languages as well as lending its vocabulary to a number of other languages.

⓬ **Russian** With 160 million native speakers and many more using it as a second language, Russian is an important language in Europe and one of six official languages of the United Nations.

⓭ **English** This widely spoken language went global through British colonization. Today, there are 400 million native speakers, and it is the most used language on the Internet.

LITERATURE

Any form of creative writing is called literature. It includes fiction, such as novels, poems, and plays, and nonfiction, including reference books, diaries, letters, and autobiographies. In all these literary forms, writers use their imagination to shape their material. They set out to convey information, ideas, or feelings in a clear and informed way that will interest and engage the reader.



Crime and Punishment is a novel by Russian writer Fyodor Dostoevsky

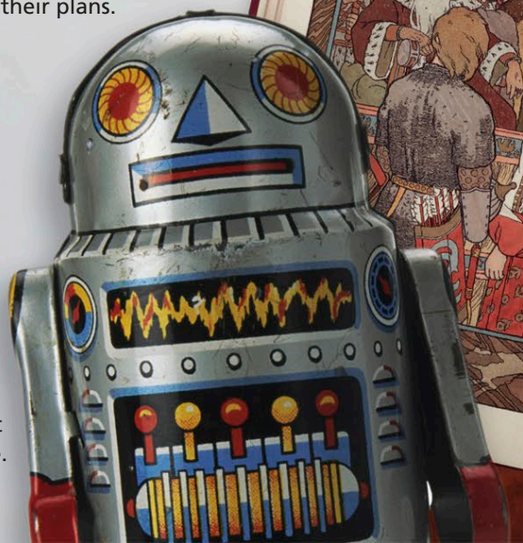
▲ FICTION
Authors who write fiction create events, settings, and characters from their imaginations. Although writers may base their stories on true events, there are always some elements that are made up. Works of fiction can include short stories, novels (long stories containing at least 60,000 words), poems, and plays.

◀ NONFICTION
Writing that is based on fact is called nonfiction. Authors need to thoroughly research and understand their subject so they can bring to life actual events—historical, political, and personal. Nonfiction titles also include biographies (accounts of people's lives) and autobiographies (authors' accounts of their own lives).

Anne Frank wrote about her experiences as a Jewish girl hiding from the Nazis in World War II

Romance This popular fiction focuses on a love story between two people, usually with a happy ending. It may take place against a modern or historical setting.

Crime This type of fiction covers the exploits of criminals and their crimes and follows the detectives who crack cases and foil their plans.

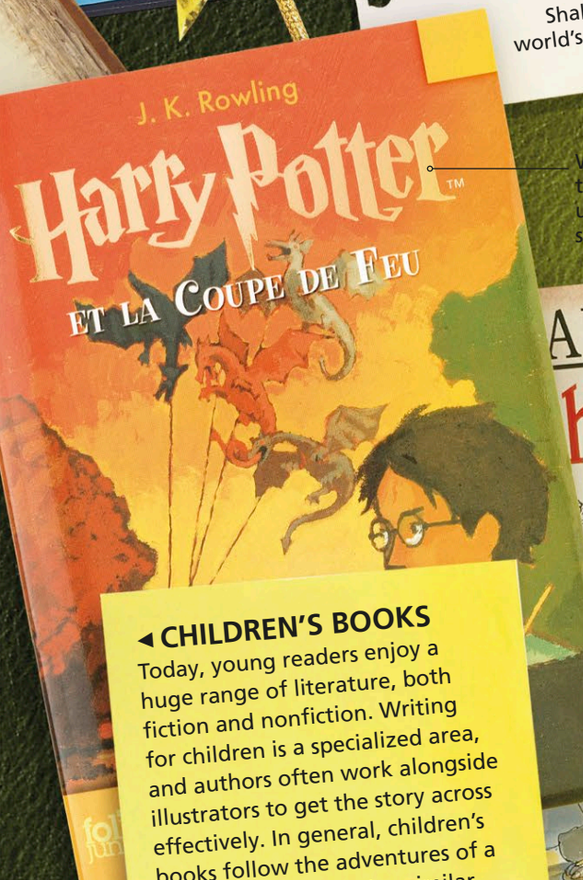


Science fiction Authors may use scientific fact and modern technology to explore and imagine an alternative world, set now or in the future.

DRAMA ▸

Stories written for an audience fall into the category of drama, which may be performed in a theater, in the movies, or on the radio or television. The audience of a drama expect something to happen, so writers use language to create characters and situations that will hold their interest.

English playwright William Shakespeare is considered the world's most successful dramatist



When a book is a success, the author may follow it up with one or more sequels to create a series

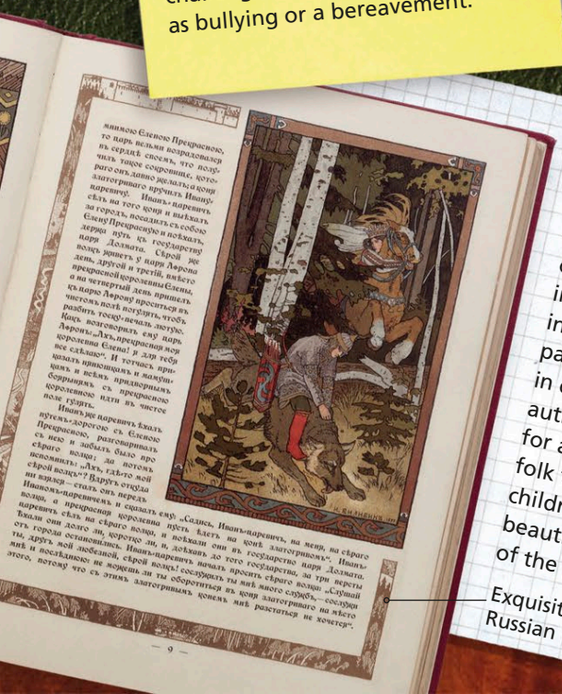
◂ CHILDREN'S BOOKS

Today, young readers enjoy a huge range of literature, both fiction and nonfiction. Writing for children is a specialized area, and authors often work alongside illustrators to get the story across effectively. In general, children's books follow the adventures of a main character who is a similar age to the reader. The story line may also introduce readers to challenges in their own lives, such as bullying or a bereavement.

BESTSELLERS

Hugely popular books that sell to vast numbers of readers are referred to as bestsellers. The biggest seller of all time is the Bible, with approximately 6 billion copies sold. Former Chinese leader Mao Zedong's *Quotations from Chairman Mao* sold some 1 billion copies. The holy book of Islam, the Quran, is close behind with 800 million copies. One of the most important works of Western literature, the Spanish novel *Don Quixote* by Miguel de Cervantes Saavedra, has to date sold about 500 million copies.

- More than 2 billion copies of Agatha Christie's crime novels have been sold worldwide.
- The bestselling playright is William Shakespeare, with an estimated 4 billion copies sold.
- The seven books in J. K. Rowling's Harry Potter series have sold more than 500 million copies.
- *The Lord of the Rings* by J. R. R. Tolkien has sold more than 150 million copies.
- The Bible has been translated into more than 2,000 languages.



◂ FOLK TALES

These magical stories usually feature fantastic characters facing near impossible challenges, set in an unspecific time in the past. The original tales, found in every culture, have no known authors. They were first intended for a general audience, but now folk tales are often thought of as children's books. They are usually beautifully illustrated with images of the people and places.

Exquisitely illustrated Russian folk tale

Basho (1644–1694) was Japan's most famous haiku poet

◂ POETRY

In contrast to prose, poetry is often written in lines rather than paragraphs. Poets choose words that will best express an image, an idea, or a feeling. Some poetry rhymes, but not all. An ancient form of poem is the Japanese haiku, which requires the poet to use words made up from 17 syllables (single units of speech) to convey an idea or image.

MEDIA

The many ways people seek to communicate information to a large audience are known as the media. This communication can be in written, spoken, printed, or digital form. Throughout history, leaps in technology from the invention of printing to growth of the Internet have led to better, faster ways of reaching people. Today, information can be relayed around the globe in seconds.

❸ TELEVISION AND MOVIES

Since the early broadcasts of the 1930s, television has brought news and entertainment to a wide audience. Today, television and movies can be watched from home. DVDs, smart TVs, and online streaming services, such as Netflix, allow viewers to choose between thousands of shows, as well as record, pause, and rewind them.

❹ RADIO

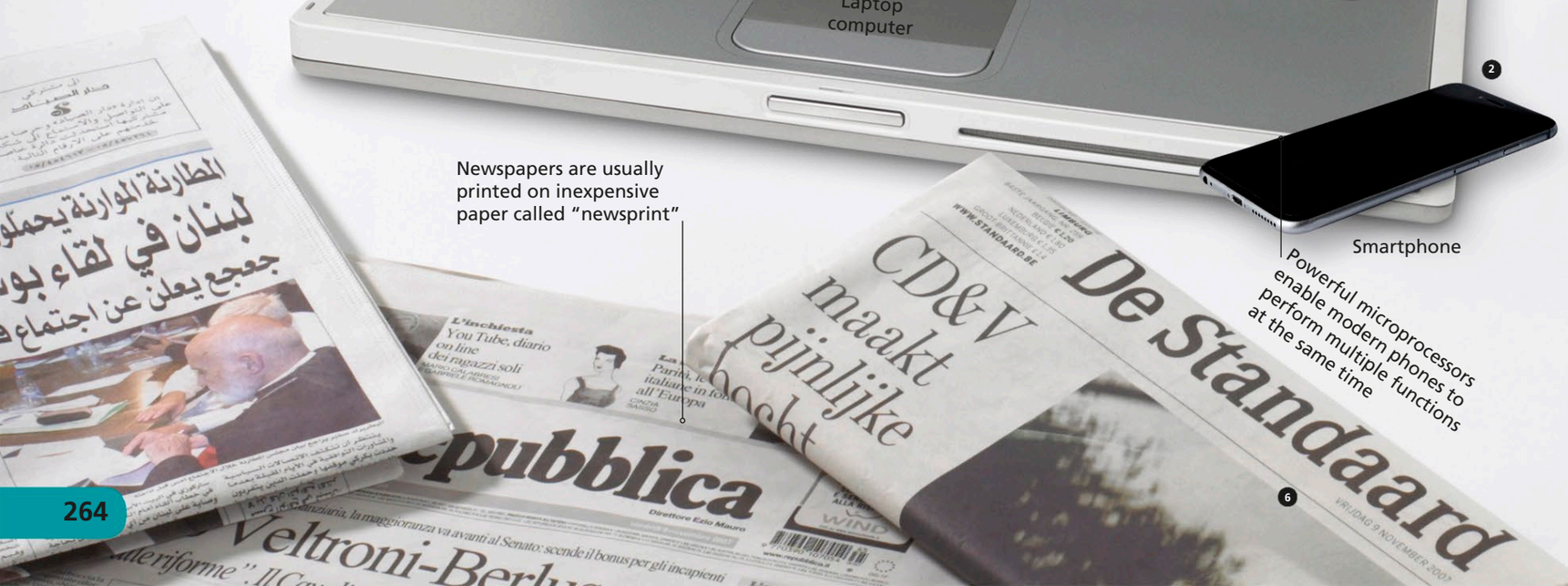
In 1938, a radio dramatization of *The War of the Worlds* in the United States convinced many listeners that an actual Martian invasion was in progress. Today, radio stations still fill the airwaves with music, talk, news, and drama.

❶ DIGITAL MEDIA

The word "digital" refers to the way that information is turned into number-based codes before being sent or stored via electronics. The Internet is the key form of digital media and has opened up mass media to the individual. Anyone with a blog or website can express opinions to a huge audience.

❷ CONVERGENCE

In this digital age, media content is available on many different platforms. News, movies, and TV programs can be viewed on smartphones, tablets, computers, and smart TVs. In addition, these digital devices also enable people to create and consume media content via social media platforms, such as Facebook and Twitter.



❺ GLOBAL NETWORKS

Media is a global business. The majority of the world's media outlets are controlled by just a handful of international companies. Satellites orbiting Earth transmit television broadcasts around the world.

❻ NEWSPAPERS

Published daily or weekly, newspapers contain news, information, feature stories, and advertising. China leads the world with more than 100 million newspapers circulating daily. Today, many papers are available to read online.

❼ MAGAZINES

The content of a magazine does not usually date as quickly as that of a newspaper. Magazines may cover current events, or they may be aimed at a specific audience, for example, movie or music fans.

PHOTOGRAPHY

Photography is a method of making pictures of the real world by capturing light from objects. Light can be captured on film–a sheet of plastic coated with light-sensitive chemicals–or by an electronic sensor. Since cameras were invented, in the early 19th century, photographers have changed the way we see the world. They have shown us the wonders of nature, microscopic bacteria, the horrors of war, distant galaxies, sports triumphs, and family portraits.

The speed of the shutter catches individual drops of water

❶ ACTION

Modern cameras are very sensitive and can open and close their shutters in a fraction of a second. This allows them to freeze a moment in time, showing a soccer player scoring a goal or a swimmer powering through the water.

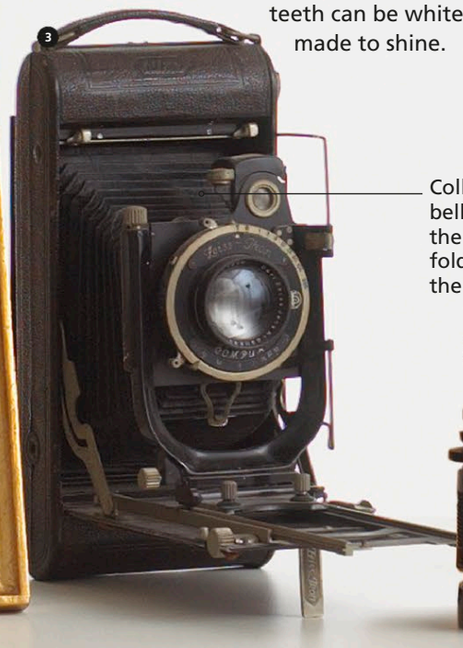
❷ PORTRAITS

Before photography was invented, only the very rich could afford to have portraits painted by artists. In the early days of photography, people wore their best clothes to strike a pose in a photographer's studio. Today, family photo albums chronicle birthdays, vacations, weddings, and everyday life.

❸ EARLY CAMERAS

The first cameras, developed in 1839, were large boxes, which had long exposure times (the time needed for photographic film or an image sensor to be subjected to light). Early sitters look stiff and uncomfortable, for they often had to hold a pose for up to 20 minutes. Over time, cameras became smaller and more sensitive to the light.

Sepia, a brown pigment derived from cuttlefish, made printed photos more durable



Collapsible bellows allow the lens to be folded back into the camera

❹ ADVERTISING ART

The photos we see most often are ads, blown up on street billboards and in glossy magazines. These photos are often "retouched" so that the models look more perfect. In a lipstick ad, teeth can be whitened and lips made to shine.

❺ LENSES

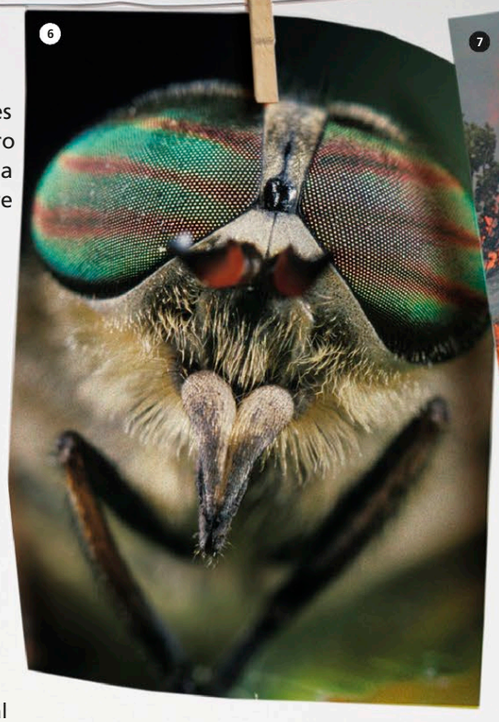
Cameras work by focusing light from objects using curved pieces of glass called lenses. A zoom lens (above) uses an assembly of several lenses. By adjusting their distance from each other, the photographer can zoom in on distant objects.

❻ MACRO

This type of photography uses a special lens to take close-up pictures of tiny objects, such as flies. A macro lens can focus only on a limited area of an object. While this fly's eyes are in sharp focus, its body is blurred.

❼ REPORTAGE

Photojournalists are reporters who use pictures, rather than words, to tell news stories. Armed with their cameras, they visit war zones and scenes of natural disasters, such as floods and fires, often risking their lives to bring back photographs that will tell an accurate story.



In a studio, a photographer can control how a shot is lit

This "portrait" view is unusual for landscape photography, which gave its name to horizontally oriented photos

❾ LANDSCAPES

Like painting, photography is used to record beautiful and often dramatic scenery. Some of the best landscape photographs are taken either in the hour after sunrise or before sunset. The sun, low in the sky, bathes the world in a warm golden glow.

❿ DIGITAL CAMERAS

Modern cameras contain computers, which record images electronically rather than on film. Photographers with digital cameras can take as many pictures as they want without wasting film. Images can also be sent easily over the Internet from one computer to another.

Lights on stands can be raised and set at different angles

❽ FILM CAMERAS

Early cameras used heavy metal or glass plates. The roll of film, invented in 1888, made cameras both smaller and cheaper. The image was captured on the film in reverse, as a negative, which was used to print positive copies on paper.

THEATER

Theater has its origins in Ancient Greece, where performances included singing and dancing as well as acting. In medieval times, plays were based on religious stories and were staged on large wagons in public places. It was not until the 17th century that theaters were built with a raised, framed platform, separating the audience from the stage by a curtain. Today, modern theaters provide the setting for performances of all kinds, from plays and pantomimes to opera and ballet.

❼ ACTORS
The success of a theatrical performance often depends on the skills of the actors, who use facial expressions, tone of voice, and gestures to make the audience believe what is happening on stage. The first recorded actor was a Greek poet named Thespis who was writing and acting out his own plays in the 6th century BCE.

❽ SCENERY
Set designers use scenery to create atmosphere, set the location of the story, and give the illusion of distance and space on stage. Above the stage is a "fly" space in which scenery and equipment hang. A complex system of pulleys hoists heavy pieces of scenery to and from the stage.

❾ STAGE
In the theater, the stage is the platform where the performance takes place. Traditionally, the stage is made from wooden boards and often contains a trapdoor through which performers and scenery can be raised and lowered.

❶ PROSCENIUM
The decorated arch that divides the stage from the audience is known as the proscenium. It acts as a picture frame for the performance on stage. This type of arch was invented in Italy in 1618, although many modern theaters now have an open stage without a curtain.

❷ CURTAIN
Made from heavy cloth, such as velvet, the curtain screens the stage from the audience while the stagehands are changing the scenery. The flameproof safety curtain prevents fire from spreading from the stage to the rest of the theater.

❸ BOX
The auditorium, where the audience sits, is made up of private boxes, tiered seats called the stalls, the dress circle, and the upper circle. Private boxes contain the most expensive seats and usually have the closest view of the stage.

❹ WINGS
The offstage areas on each side of the curtain are called the wings. Concealed by the proscenium, the actors wait in the wings before they make their entrance on stage.

5 COSTUMES
The actors' costumes are the responsibility of the wardrobe department. The wardrobe manager researches, designs, and looks after the costumes and helps the actors change outfits between scenes.

6 ORCHESTRA
Beneath the front of the stage is the orchestra pit, where the musicians and sound technicians sit. The conductor stands facing the stage to coordinate the music in time with the actions of the singers, dancers, and actors.

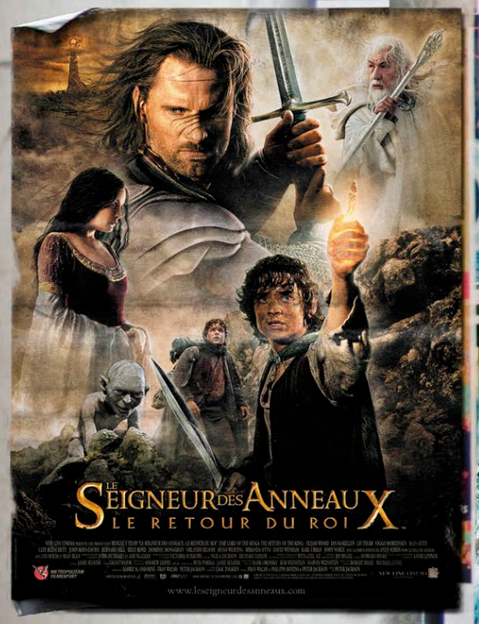
MOVIES

From 1895, when the Lumière brothers first delighted French audiences with their "moving pictures" to today's multibillion-dollar film industry, movies have become a popular type of entertainment, an important art form, and a way to shape people's opinions. The "magic" of movies is that they are created from a series of individual images shown in rapid sequence.

▼ SILENT
Until the late 1920s, the technology to add recorded sound to movies did not exist. Instead, bits of dialogue or key story points appeared as words on screen, and actors relied on body language. Live piano music helped set the mood.

▼ WESTERN
Set in the tough American West, these movies captivated huge audiences in the 1950s and '60s. Westerns tell of cowboys, outlaws, gunslingers, and good guys as they faced the challenges of frontier life.

▼ HORROR
These movies are created to terrify and shock the audience. In a typical horror film, characters must overpower evil—be it a monster, a ghost, or a serial killer. Horror films are often quite violent and gory.



▲ SCI-FI AND FANTASY
Imaginative and visually stunning, science fiction and fantasy allow filmmakers to explore future worlds, use special effects, and speculate about our relationship with technology.

▲ ACTION-ADVENTURE
These movies often follow the exploits of a hero, with plenty of fast-paced stunt work, chases, fistfights, and shoot-outs. From intrepid crime fighters to special agents, these daring heroes always save the day.

▲ ANIMATION
These movies are created when a rapid sequence of drawings (or models) is run together to give the illusion of movement. Animation also uses computer-generated images (CGI).

▼ BOLLYWOOD

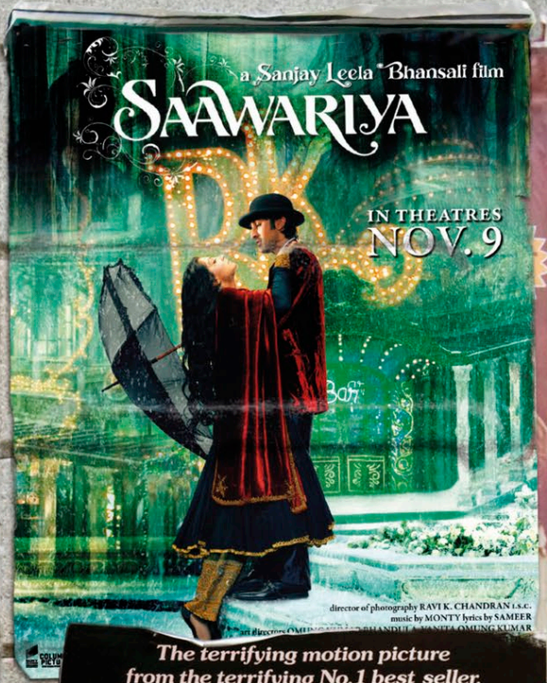
From the early 1900s, Hollywood has been the center of moviemaking. Today, more than 1,000 movies a year are made in India. Many are lavish, colorful Bollywood musicals (the name is from the "B" in Bombay, the old name for Mumbai).

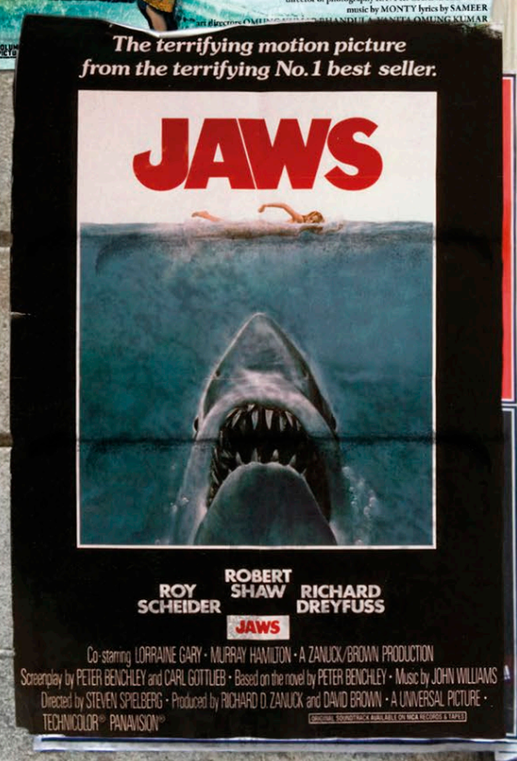
▼ COMEDY

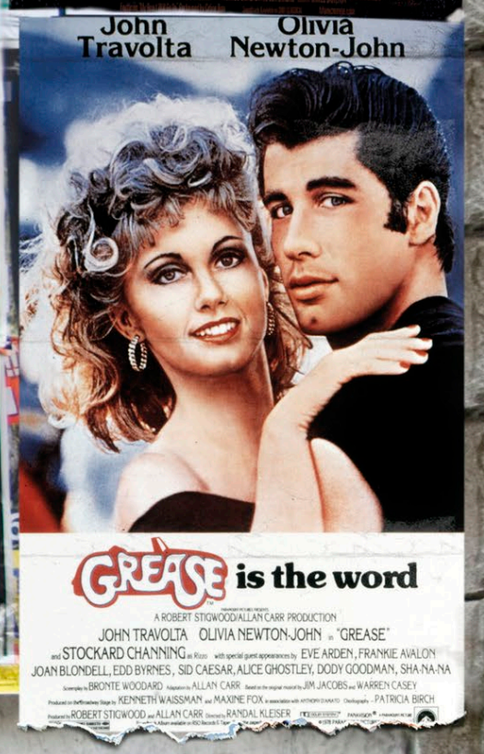
From slapstick to spoofs, audiences have always loved comedy movies. Some rely on the dialogue for the laughs; others on physical quirks of the actors—or a combination of both. These movies often have happy endings, even if they explore the darker side of life.

▼ DISASTER

Asteroids hurtling to Earth, shipwrecks, and earthquakes have all been subjects of disaster movies. Since the 1990s, the introduction of CGI special effects has made it easier to create visually spectacular disasters.







▲ THRILLER

Action-packed and fast-paced, thriller movies create audience tension as the hero tries to outwit an evil adversary. Some thrillers feature plenty of action, while others rely on creating an atmosphere of suspense.

▲ MARTIAL ARTS

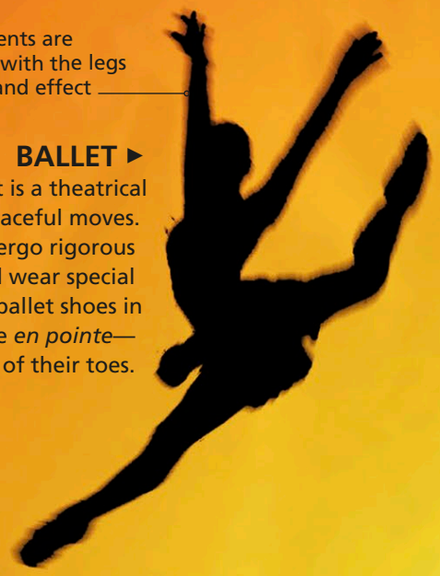
These Asian-based action films feature spectacular fight sequences using one or more of the martial arts. Among the martial artists who became stars due to their skills are Bruce Lee and Jackie Chan.

▲ MUSICAL

Featuring singing and dancing as part of the storytelling, musicals are often adapted from stage productions. Recently, Hollywood musicals have played to wide audiences in a revival of the genre.

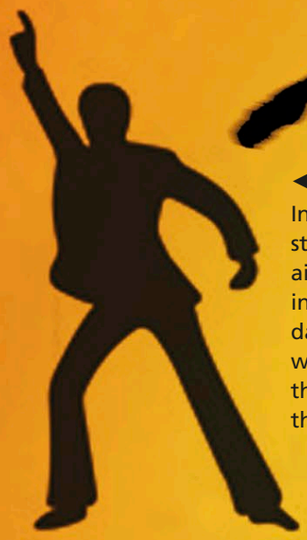
DANCE

Energetic or graceful, dancers use athletic skill and flexibility to perform a series of movements, often in time to music. Dancing is a form of expression that may be a type of performing art, part of a special ritual, or a fun social activity. The earliest dancers used movement to worship gods and spirits and to act out stories. In performances, dancers often follow a preplanned series of steps and movements devised by a choreographer.



Arm movements are coordinated with the legs for balance and effect

BALLET ▸
Ballet is a theatrical dance with graceful moves. Dancers undergo rigorous training and wear special hard-toed ballet shoes in order to dance *en pointe*—on the tip of their toes.



◂ DISCO
In the 1970s, pop songs with strong dance beats ruled the airwaves, and people gathered in clubs to disco dance. Some dances had set steps; others were created by the dancers themselves, perhaps inspired by the film *Saturday Night Fever.*

The dragon is a symbol of power and strength. The longer the dragon, the more luck it will bring

Bamboo poles help the dancers move the dragon in a realistic way

CHINESE DRAGON DANCE ▸
In this ceremonial dance, dating back to the Han Dynasty (206 BCE–220 CE), a team of performers carries a colorful dragon, held up with poles. They lift and lower the poles to make the dragon dance. This dance is a key part of Chinese New Year celebrations.

BHARATANATYAM ▸
In ancient times, Hindu temple dancers in south India performed a set of moves and postures to tell the stories of the gods. These evolved into the Bharatanatyam dance style. In this dance, certain poses—especially hand gestures—are held to represent different meanings.

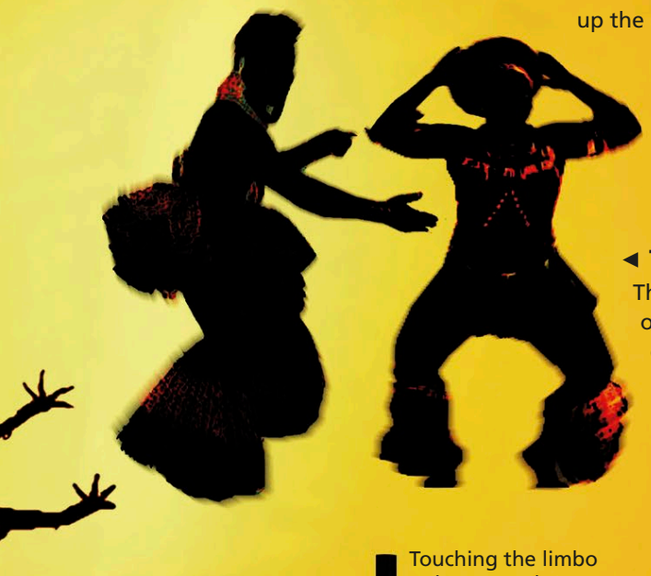
◄ TANGO

This dramatic dance for couples began as a street dance in Argentina and Uruguay during the mid-1800s. With hands tightly clasped, dancers either face each other or look in the same direction as they move to the beat. Tango is also the name for the music associated with the dance.

CAN-CAN ►

This high-kicking, cartwheeling dance began in Paris in the 1830s and was originally for couples. French dance troupes soon took up the can-can in music halls, where chorus lines of girls performed the energetic dance.

Dancers swirl their skirts and petticoats as part of the performance



◄ TRIBAL DANCE

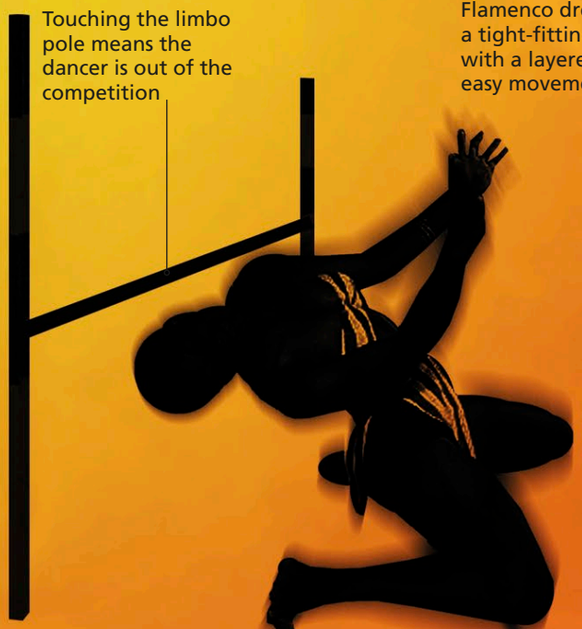
These traditional African dances, often performed to the beat of a drum, are important parts of many ceremonies, both joyful (weddings and coming-of-age celebrations) and sad (funerals). Tribal dances help unite and uplift the community.

Castanets were not originally part of "true" flamenco but were introduced to add drama

Flamenco dress features a tight-fitting bodice with a layered skirt for easy movement

▲ FLAMENCO

With its roots in small villages of the Andalusian region in Spain, flamenco is a passionate style of music and dance with a strong, powerful rhythm. Dancers click their fingers and stamp their feet to match the drama of the guitar music.



Touching the limbo pole means the dancer is out of the competition

LIMBO ►

The limbo was created in the Caribbean Islands. Performers have to dance under a horizontal pole without touching it or losing their balance. The pole is lowered after each round until one limbo champion dancer remains.

MUSIC

Music is a performance art created by the sounds of singers and instruments and covers an incredible range of styles. It can be enjoyed live or through various media forms from television and radio to the Internet. Music has always been written and performed, but it was not until the 20th century, when new technology to record and share music developed, that musicians could become global stars.

❶ DISCO

In the 1970s, pop music with a dance beat known as disco (from *discothèque*, a French word for nightclub) filled dance floors across the globe. Disco music topped the charts and created major stars but faded from popularity in the 1980s.

❷ CLASSICAL

Classical music is a general name for the various types of music written to be performed in a concert hall. It may be composed for the instruments of an orchestra (either a full symphony or a small group of players) or written for a choir or opera company. The music of composers like Bach and Beethoven is still popular, centuries after it was written.

❸ MUSIC AND VISUALS

From the late 1970s, bands made short music videos to accompany and promote their songs. The arrival of music video networks and the Internet has created a huge boom in this area. The virtual band Gorillaz, who previously existed only as cartoon animations in music videos, turned the form on its head in 2005 when they performed live as a normal band.

❹ DANCE

The popularity of electronic instruments like synthesizers, and the ability to use computers to make music, led to a new generation of music written to fill the dance floors. DJs became stars, using turntables to mix live music.

A disco ball hung over the dance floor was a regular feature of discotheques

A score (manuscript of musical notes) is used by classical musicians so they can keep track of which parts they play

A relatively modern instrument, saxophones became key to the emerging jazz sound

Turntables and vinyl records are used by DJs to create and mix live music

Rapping evolved when DJs used microphones to talk—or "rap"—over music

Touring provides a major income stream for today's global pop stars, such as Justin Timberlake

❺ JAZZ

Jazz was born in early 20th-century America, when elements of European music were blended with the rhythmic music brought by African slaves to the South.

❻ ROCK

In the 1940s and '50s, rock-and-roll music sprang up in the United States. It was played on electric guitars, bass guitars, and drums, and featured exciting vocals, catchy tunes, and a strong beat. This evolved into rock music, a group of many diverse styles that remains popular worldwide.

❼ POP

This type of rock music is aimed mostly at a young audience. Pop songs can be fairly simple in their structure, with lots of repetition in the lyrics, so it's easy to sing along. Today's major pop stars reach an international audience with their hit songs.

❽ R&B

Rhythm and blues, or R&B, music started in the United States in the 1940s, originally performed by and for a mainly African American audience. Today's version of the style is closely related to disco and dance music but is smoother and features softer vocals.

❾ REGGAE

This style of music originated in Jamaica in the 1960s. It has a characteristic rhythm style and a slow and steady tempo (speed). The bass guitar keeps the rhythm and is the most prominent instrument. Reggae is associated with the Rastafarian religion.

❿ COUNTRY

Mixing the traditional music of the southern states of the US with rock and roll and other musical styles, country music is one of the largest-selling music genres today, with major stars, huge record sales, and enormously successful tours.

Rock band The Killers's first album, *Hot Fuss*, is estimated to have sold more than 7 million copies worldwide

Women singers, such as Beyoncé, are among the world's top-earning pop stars

Jamaican music legend Bob Marley is the most famous reggae star

The electric guitar is the main instrument in many musical styles, especially rock

Many country music stars have adopted the cowboy image

Wireless speakers can be paired wirelessly with many devices, such as smartphones, to play music anywhere

Smartphones are now used to store and listen to music

ORCHESTRA

An orchestra is a large group of instrumental musicians playing together under the direction of a conductor. Orchestras usually include four sections: percussion, brass, woodwinds, and strings. Players of similar instruments sit together, with the conductor keeping time upfront.

❶ PERCUSSION

These instruments make sounds when struck and include items that can be tuned to different notes (glockenspiels and xylophones) as well as those that cannot (drums, cymbals, and triangles).

❷ BRASS

Blowing air through hollow brass tubes produces sound in instruments such as trumpets and French horns. The note is changed by pressing down valves.

❸ LOW BRASS

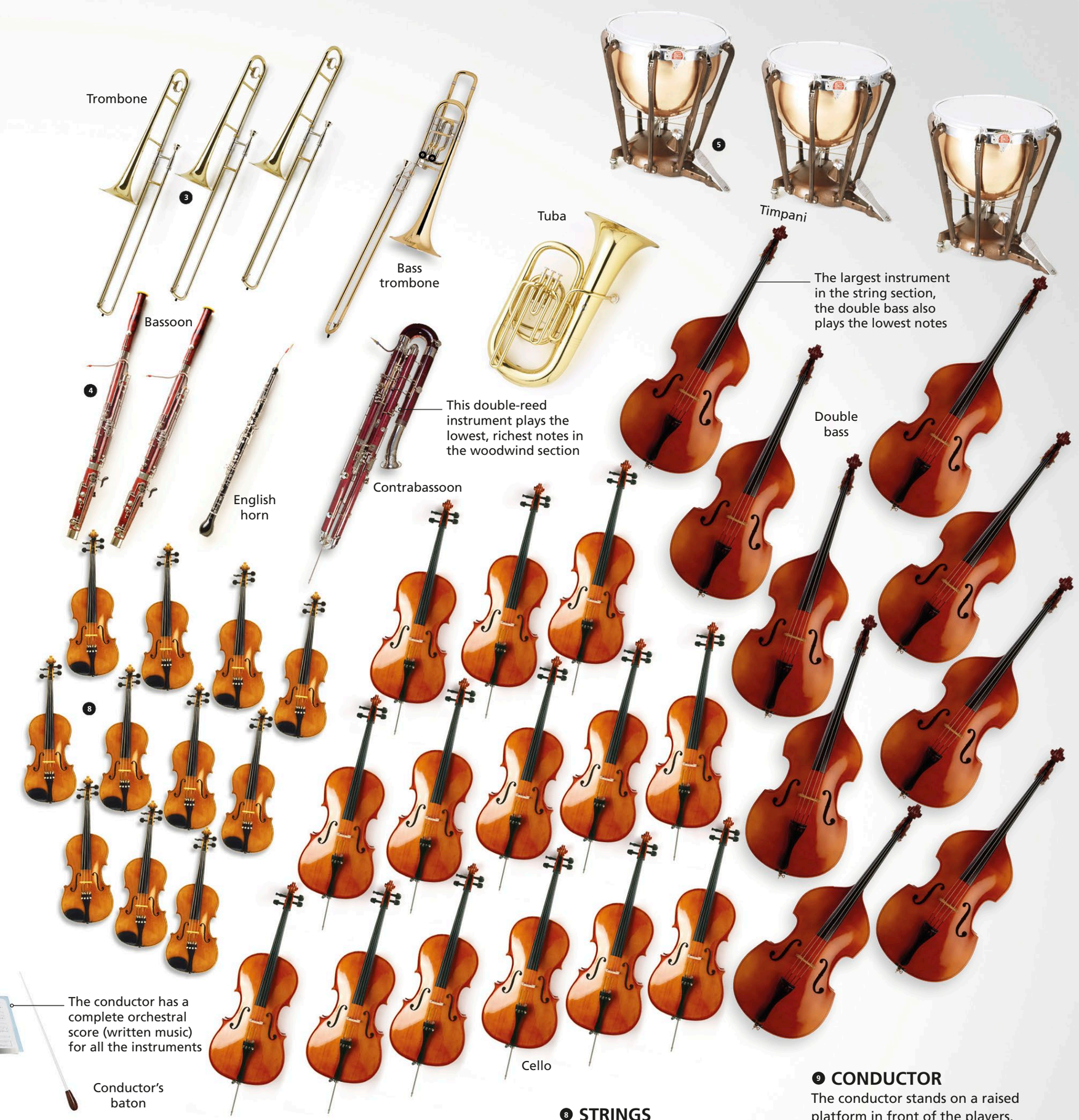
Trombones, bass trombones, and tubas play the middle to lower brass notes in the orchestra. The trombone has a slide that moves up and down to change the note. The tuba plays the lowest notes, which boom out from its bell-shaped end.

❹ WOODWINDS

This section of the orchestra includes piccolos, flutes, clarinets, bass clarinets, oboes, English horns, bassoons, and contrabassoons. Players blow air over a hole or through a reed to make notes.

❺ TIMPANI

These percussion instruments are giant copper bowls with skinlike heads struck by wool-topped sticks. They are also called kettledrums.



❻ HARP

A harp has a triangle-shaped wooden frame with 47 strings attached. The harpist plays the high notes on thin strings and the low notes on thicker ones.

❼ VIOLIN

There are more violins than any other instrument in the orchestra, and it is the smallest member of the string section. Players make notes by moving a bow across its strings.

❽ STRINGS

The strings often carry the melody (tune), and there are more string instruments than any other type in the orchestra. The section includes violins, violas, cellos, double bass, and harps.

❾ CONDUCTOR

The conductor stands on a raised platform in front of the players. The conductor's main tasks are to lead the orchestra and keep everyone in time by waving a baton to the beat of the music.

SPORTS

Many sports developed from ancient times, when running and throwing skills were essential to survival. Any activity governed by rules and requiring physical ability is considered a sport–and at the heart of many sports is a ball.

1 Hurling This fast-paced Irish game involves teams of 15 "hurlers" with ax-shaped sticks, two goals, and a small ball.

2 Football Points are scored by players carrying or throwing an oval ball into the opposition's area.

3 Polo This ball game is played on horseback. Riders use long-handled mallets to drive a ball into the goal.

4 Soccer The world's most popular sport involves two teams of 11 players trying to score goals in the opposition's net, with each game lasting 90 minutes.

5 Hockey In this game, two teams armed with hockey sticks try to score by smashing a ball into the opponent's net.

6 Shotput Players compete to throw a 16 lb (7 kg) metal shot as far as possible.

7 Gaelic football With its roots in an ancient Irish game called caid, players score by kicking or hitting the ball through H-shaped goals.

8 Aussie Rules football Players pass the oval-shaped ball to teammates by kicking or throwing it. To score, they must kick the ball between four posts at each end of the field.

9 Juggling balls Jugglers keep several balls in the air at once. Experienced jugglers can swap balls for knives and fire torches.

10 Lacrosse Players catch and throw a rubber ball with netted sticks in this sport invented by Native Americans. They must throw it into the opposition team's goal to score.

11 Softball In this team sport, players use a bat to whack a ball as far as possible to give them time to run around four bases.

12 Rugby Players attempt to gain points by landing the oval ball beyond the other team's goal line or kicking it over a high H-shaped goal.

13 Medicine ball Athletes put these weighty balls on their bodies to increase their muscle strength while exercising.

14 Baseball This sport is very similar to softball but played with a smaller, harder ball.

15 Cricket A bowler throws the ball at a wicket (set of wooden poles), which is defended by a batsman.

16 Golf A club is used to hit a small ball a long distance to get it into, or as near as possible to, each hole on a course.

Rugby balls are oval shaped to make them easier to hold against the upper body while running

Modern soccer balls have 32 stitched panels

Medicine balls can weigh from 5 to 15 lbs (2.5 to 7 kg)

17 Boules Very popular in France, players compete to throw heavy balls at a much smaller ball, called a jack.

18 Bowls On well-maintained lawns, players try to roll balls closer to a small target ball than their opponents.

19 Snooker Using sticks called cues, two players attempt to pot 15 red balls and six different colored balls into six pockets on a special wool-covered table.

20 Rounders Two teams take turns at batting and fielding. A rounder is scored when a player hits the ball far enough to run around four posts before the ball is returned by a fielder.

21 Basketball The game was first played using peach baskets on poles for hoops. If a team scored, the referee climbed a ladder to get the ball.

22 Netball Based on basketball, this team sport is played on courts and is most popular with women in Australasia.

23 Volleyball Two teams of six players compete to pass a ball over a high net using only their hands. If the ball touches the ground, the other team gains points.

24 Croquet French peasants in the 14th century used wooden mallets to whack a wooden ball through hoops crafted from bent branches, inventing the game of croquet.

25 Tennis Played on grass or clay courts, two players (singles) or four players (doubles) use rackets to hit a felt-covered ball over a net.

26 Pool Similar to snooker, two players use cues to sink either red or yellow balls into pockets. The winner is the player who sinks the final black ball.

27 Squash Inside a walled court, players take turns to smash a rubber ball with a racquet against the wall.

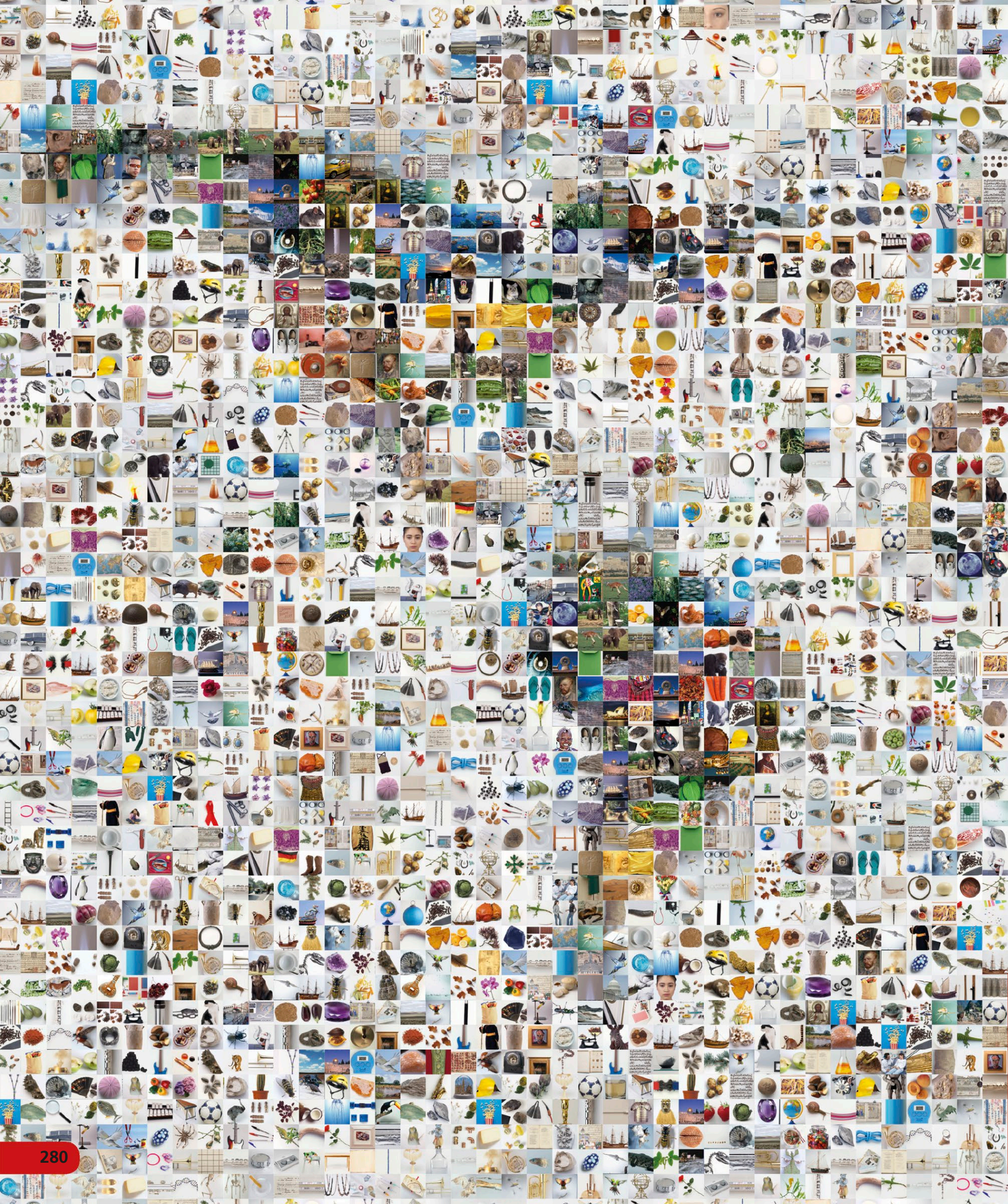
28 Beach volleyball First played on California's sandy beaches in the 1920s, this sport can now be played on artificial sand courts.

29 Table tennis This sport began in Victorian England, when dinner guests turned their table into a mini tennis court. Champagne corks were used as balls.

30 Water polo Players swim to catch the ball to stop the opposing team from reaching their goal.

31 Tenpin bowling Players hurl a heavy ball down a wooden lane to knock down the 10 pins.

32 Marbles Players compete to throw glass marbles inside a designated circle or at another target marble.



Reference

Nature

Lichen are only an inch or so tall, but they **live for a very long time** in the coldest places on Earth. Some lichens in **Antarctica** are more than

4,000 years old.

After a **tree dies,** all the carbon dioxide it absorbed when alive is eventually released back into the **atmosphere**. The same amount of **carbon dioxide** is released whether the tree burns or rots.

The **largest water plant** is the Amazonian giant lily. Its leaves are **so big** that a child could **sit on it without sinking.**

Magnolias are among the most ancient flowering plants. **Fossils** of magnolias have been found that are

20 *million years old.*

The ***nepenthes*** is the world's largest ***carnivorous*** (meat-eating) plant. It catches insects in its huge ***vase-shaped*** pitcher leaves. It is sometimes called the "monkey cup" because monkeys like to drink out of its ***pitchers.***

Fungi live by **feeding** on dead organisms or their waste. **Pilobolus** fungi feed on cow dung.

*The **largest fungus** ever found is an* Armillaria ostoyae *in Oregon, which covers nearly 4 sq miles (10 sq km) of forest floor and is estimated to be up to **8,500 years old.***

The **streaks of color** in cheeses such as **Stilton** and **Danish Blue** are made by **mold**, which is a microscopic fungus.

A typical bed is home to about ***2 million*** *dust mites.*

Many desert plants have **very long roots** to **find water** deep underground. The tropical American mesquite tree's roots grow up to

150 ft (50 m) long.

Tiny nanoplankton, less than 20 thousandths of a millimeter in diameter, are the **most plentiful organisms** in Earth's oceans.

The smallest flowering plant is the duckweed ***Wolffia***, which is just 0.6 mm long.

Aphids are born pregnant and can **give birth** just **10 days** after they are born themselves.

European eels lay their eggs in the oceans. The baby elvers then make their way to freshwater rivers. A female eel can lay up to

4 million

eggs in one year.

The seeds of the **coco de mer** are the largest of any plant. They can weigh up to 45 lb (20 kg).

*One type of **lungfish can breathe** underwater **using gills** and in the air **using lungs**.*

The **smallest mammal by weight**, the **Etruscan shrew**, weighs just 0.06 oz (1.8 g)—**lighter** than a penny.

A domestic rabbit can give birth to up to **20** babies a month.

The hummingbird is the only bird that can fly straight up, down, and backward.

Bamboo is the tallest grass. It can grow up to **150 ft** (50 m) tall.

A male walrus's tusks can grow up to **3 ft** (1 m) long.

A **male howler** monkey's **howls** can be **heard** up to 3 miles (5 km) away.

Freshwater and saltwater **crocodiles cry**. They do it to lubricate the eyes and get rid of excess salt in their bodies, not because they are sad.

Sharks have a very good sense of smell. They can detect *one* part of blood in *100 million* parts of water.

Prairie dogs live in huge burrows called towns. One town in Texas was home to

400,000,000 individuals.

A woodpecker can peck up to **20** times per second.

The digestive juices of a hyena are strong enough to break down bones.

Octopuses have three hearts—two to pump blood to their gills and one to pump blood around their bodies.

Ants *never* sleep.

There is enough poison in a single *poison dart frog's* skin to kill **10,000** mice.

The **pregnancy** of an Indian **elephant** lasts for about 22 months.

The biggest living cat is the Siberian tiger, which weighs up to 660 lb (300 kg).

A mole can tunnel through **330 ft** *(100 m) of earth in a day.*

Some species of springtails, a kind of **insect**, can survive in temperatures as low as –36ºF (–38ºC) because their bodies contain **antifreeze**.

A red **kangaroo** can cover **25 ft** (8 m) in a single **hop**.

The world's **largest** living **rodent**, the capybara, can weigh up to **140 lb** (65 kg).

A **termite** queen lays **30,000 eggs** a day.

Whale milk is nearly **50% fat**.

The blue whale is the largest animal that has ever lived. Its heart alone can weigh **400 lb** (180 kg).

China's earthquake **early warning** system involves the close monitoring of **snakes**, which leave their nests shortly before an **earthquake**.

A pile of **elephant dung** may contain **7,000** beetles.

Male humpback whales sing songs that last **20 minutes** or longer. They may be doing this to ***serenade*** females.

Camels can go up to **two weeks** without drinking, but when there is **water** around, they can down 40 gallons (200 liters) in 10 minutes.

There are more than **370,000** known species of **beetles**.

Monarch butterflies migrate **2,500 miles** (4,000 km) from North America to Mexico or Butterfly Grove in San Francisco to **spend** the winter, even though they have **never been there** before.

A **bee's buzz** is made by its wings, which flap **250 times a second**.

A dog can make about 100 different **facial expressions**, most of them involving its **ears**.

*The part of a **dog's brain** involved in **sensing smell** is **40 times** bigger than that of **humans**.*

Cows have four stomachs, which they use to **process** hard-to-digest grass and **vegetation**.

Beaver **dams** can be **1,000 ft** (300 m) **long** and may be ***hundreds*** of years old.

Spiders usually prefer to live alone but very occasionally team up to build **huge webs**. A web found in 2007 in Lake Tawakoni State Park in Texas measured 600 ft (180 m) across. It was built by **lots** of different **species** of spiders.

A blue **whale's whistle** can be heard more than 60 miles (600 km) away **underwater**.

Whales and dolphins put **half their brains** to sleep at a time so that they **don't drown**.

A **flea can cover 12 in** (30 cm) in one jump—that's 200 times the length of its own body.

With a wingspan of up to **11 ft** (3.5 m), the ***wandering albatross*** has the longest wingspan of all flying birds, which means that each of its wings is ***almost as long*** as an **adult human** is tall.

LEARN MORE ABOUT THE NATURAL WORLD ON PAGES 8–59

Human body

Your body sheds tens of thousands of **skin flakes** every minute. Over a lifetime, a body loses **45 lb (20 kg)** of skin flakes.

*The liver handles more than **500** different jobs, including the disposal of dead blood cells, making proteins, and storing sugars.*

There are **100 trillion cells** in your body. A billion of them die every 20 seconds.

There are more muscles in a caterpillar than there are in a human body.

You lose **100,000** brain cells every day.

Your brain weighs about 2 percent of your total body weight but uses 20 percent of your blood supply.

The largest human cell is the female ovum.

The smallest is the male sperm.

The brain of an adult is **three times heavier** *than that of a newborn baby. From the age of 20, the brain loses* **1/30 oz** *(1 g) a year as* ***brain cells die*** *and are not replaced.*

You spend ***half an hour*** every day blinking.

The left lung is smaller than the right lung to make room for the heart.

It takes about 40 hours for food to pass through the large intestine.

Everyone has a unique tongue print.

Your **eyes** stop growing when you reach puberty and stay the same size for the rest of your life.

At rest, you **breathe** about once **every four seconds**. This rises to once every second during exercise.

Women's hearts are smaller than men's, but they beat on average 75 times per minute compared to 70 times for men.

Nose hairs act like a net to trap and remove nasty particles from the air.

We make 2 pints (1 liter) of saliva in our mouths every day.

About **a third** of adults snore.

The bones in the hands and feet account for more than half of the bones in the human body.

Tiny bacteria make up 3 percent of your body weight.

Stretched out straight, the small intestine is about 19 ft (6 m) long.

Food spends up to six hours in your stomach being digested.

The smallest muscle in the human body is the stapedius. It is inside the ear and is less than 0.8 in (2 mm) long.

There are more than

600

muscles in the human body. Muscles are 40 percent of the body's total weight.

Blood travels 12,000 miles (19,000 km) every day. That's half way around the world.

After the age of **60**, you will lose about half of your taste buds.

The **stomach** continually produces new layers of mucus to protect the lining and stop the stomach from digesting itself.

The average person eats **30 tons** of food in a lifetime—that's the weight of **80 horses**.

There are around 1,000 trillion bacteria in your body—10 times more than the number of body cells.

The loudest snore ever recorded was more than 80 decibels, as loud as a pneumatic drill.

The average human head has 100,000 hairs growing on it, but redheads have only 90,000.

An **adult man** normally needs to **eat** about **2,500 calories** (10,000 kilojoules) a day. ***Arctic explorers*** need about ***three times*** that much to keep them going in the ***cold***.

A fingernail would grow 28 m (90 ft) long if never cut. The middle nail grows fastest, the thumb slowest.

There are the same number of hairs on the body of a human being as on a chimpanzee.

The longest beard ever measured was more than **16 ft** (5 m) long and belonged to Norwegian ***Hans Langseth.***

Babies start dreaming before they are born.

The average human blinks 23 times a minute. That's 12 million times a year.

A body releases 4 pints (2 liters) of gas per day as burps or farts.

The largest organ is the skin, which has a surface area of about 20 sq ft (2 sq m) and weighs about 22 lb (10 kg).

Babies don't have bony kneecaps. Their soft kneecaps begin to become bony between the ages of 3 and 6.

73 percent of babies' bodies are water. This drops to 60 percent in adult men and 55 percent in adult women.

The most common time of birth is between 3 a.m. and 4 a.m.

There are 250,000 sweat glands in a pair of feet. They can produce half a pint (a quarter of a liter) of sweat in one day.

Standing upright burns up 140 calories (600 kilojoules) of energy in an hour.

One in **2,000 babies** is born with a **tooth.**

In an average lifetime, you will walk the equivalent of five times around the equator.

The first successful heart transplant took place in 1967. There are now eight heart transplants in the US alone every day.

The largest artery, the **aorta**, is about **0.78 in** (2 cm) in diameter. That's as wide as a **hose pipe**.

During puberty, boys can grow 3.5 in (9 cm) in a year.

Children grow faster in spring.

When you sleep, you lose up to 14 oz (42 g) in weight every hour.

Common colds can be caused by one of more than 200 types of viruses.

A cough releases air at speeds up to *60 mph* (100 km/h).

A single sneeze might contain up to 100,000 viruses.

More people died during the flu pandemic at the end of World War I than were killed during the war.

19th-century British surgeon Robert Liston could cut off a leg in ***28 seconds***.

Life expectancy at birth in Japan is 84.2 years—the highest in the world.

You cannot ***sneeze*** with your eyes open.

In a whole lifetime, a human passes **12,000 gallons** (45,000 liters) of urine. That's enough to fill a **swimming pool**.

In your lifetime, you will drink about 18,500 gallons (70,000 liters) of water.

The **oldest** person ever documented was French woman ***Jeanne Calment***, who **died** in **1997** aged **122 years** and **164 days.**

SEE AND EXPLORE THE HUMAN BODY ON PAGES 60–87

Science and technology

Google processes more than 5 billion searches every day.

The **smallest particle** scientists have found is the **quark**. It is **so small** that nobody has seen one, and we only know it is there because of its **effect** on things **around it**.

The number zero was first used in India around 875 BCE.

The **smallest** Standard International (SI) **unit of weight** is the **yoctogram**, which was added to weigh **subatomic particles**. The **largest unit**, the **yottagram**, is used to **weigh stars** and planets—Earth weighs in at 6,000 yottagrams.

***Atoms** are mostly made of **empty space**. If the **nucleus** were a fly in the middle of a soccer field, the **electrons** would be like dust particles **flying around** in the stands.*

A proton is 1,835 times **heavier** than an electron.

The **densest naturally occurring element**, osmium, **weighs** 13 oz/in^3 (23 g/cm^3).

Scientists in Europe are developing a laser that will produce light 10 trillion times as bright as sunlight.

***Thomas Babbage** came up with his idea for a **computer** when he was just **19 years old**.*

The Internet domain name ***business.com*** was bought by Marc Ostrofsky in 1999 for ***$7.5 million***.

Airships **float** because they are filled with **helium**, a gas that is many times **lighter** than air.

At atmospheric pressure, **carbon dioxide** turns from a **solid** into a **gas**, without melting, at –108°F (–78°C).

When a **gas condenses** into a liquid, it takes up, on average, **1,300** times less space.

*The **metal lithium** is so light that it floats on water.*

Diamonds are formed from **carbon** that is **compressed** 90 miles (150 km) below Earth's surface.

A ***jiffy*** is a ***unit of time*** equal to one hundredth of a second.

*In June 2018, Summit became the world's fastest **supercomputer**. It can operate at a speed of **200 petaflops**—that is 200 million billion calculations per second.*

Tungsten has the **highest melting point** of any metal. It remains a **solid** until the **temperature** reaches **6,192°F** (3,422°C), when it finally melts.

The study of large numbers is called googology.

There are **six** kinds of **quarks**, which scientists have named up, *down*, top, *bottom*, **charm**, and **strange**.

One byte in a computer's **memory** is made up of eight **bits**. A group of four bits is called a ***nibble***.

With the help of **computers**, more recorded data has been produced in the last **10 years** than in all of previous **recorded history**.

***Hydrogen** is the lightest, simplest, and by far the most **common element** in the universe—**93 percent** of all atoms are hydrogen atoms.*

Acid rain caused by industrial **pollution** was first noticed in the Midlands, UK, in the **19th century**.

Pure water has a **neutral pH of 7**, but **rainwater** is **acidic**, with a **pH of 6 or less**.

The *first-ever email* was sent by American Ray Tomlinson in 1971. The *message* was sent from one *computer* to another right *next to it*.

There is the **same** amount of **water** on **Earth** now as there was **2 billion years ago**.

Sound can damage **your hearing** at 90 decibels (dB), the volume of very **heavy traffic**. It starts to become painful when it exceeds 130 dB, a **plane taking off**.

Noise *is a jumble of different* ***frequencies*** *of sound.* ***Musical notes have*** *one dominant frequency. Middle C has a frequency of 256 hertz.*

The scale used to measure **light intensity** uses a unit called a **candela**. It was originally based on the amount of light given out by a candle. A **flash of lightning** gives off 8.6 million candelas per sq ft (80 million per sq m).

In a vacuum, light travels at a speed of **983,571,056 ft** (299,792,458 m) per second.

On a **sunny day**, 1,000 trillion **photons** (light particles) hit an area the size of a pinhead every second.

A normal **light bulb** *turns just 5 percent of the electrical energy it is powered by* **into light**.

Red *is the* ***longest*** *visible* ***wavelength*** *of light at about* ***0.7*** *micrometers.*

Blue light travels further through **water** than **colors** with a longer **wavelengths**, such as red or green. This is why everything **looks blue** underwater.

The most powerful man-made laser is a ***million times*** brighter than ***sunshine***.

The first telephone cable under the Atlantic Ocean was laid in 1956.

Ultrasound scans use high-frequency sound at around 10 million hertz to give **an image** of a baby in the womb.

X-ray technology has shown that there are **three different versions** of Leonardo da Vinci's *Mona Lisa* under the visible one.

The ***first ever robot*** was probably built in ***Ancient Greece*** by Archytas of Tarentum ***2,500*** years ago. It was a ***mechanical bird*** powered by ***steam***.

Maglev trains are powered by **strong magnets**. The fastest commercial Maglev train is in **Shanghai**, China. It covers the 19 miles (30.5 km) from the airport to the city center in just **7 minutes 20 seconds**, reaching a top speed of 268 mph (431 km/h).

There are **7,000 robots** in the US military. They carry out dangerous work such as ***bomb disposal***.

The world's largest airliner, the Airbus **A380 "Superjumbo,"** can carry up to 853 passengers.

The ***maximum speed*** *(terminal velocity) of a* ***skydiver****, if he pulls his limbs in, is* ***200 mph*** *(320 km/h).*

The *pocket calculator* was invented in *1966* by Texas Instruments.

Wilhelm Conrad Röntgen won the first **Nobel Prize** for physics in **1901** for his discovery of **X-rays.**

Mercury is the only metal that is **liquid** at room temperature.

Two-thirds of the ***water*** *used in the home is used in the* ***bathroom****.*

It is not safe to ***skate*** on ***ice*** until it is at least ***5 in*** (13 cm) ***thick***.

More than two-thirds of the energy stored in **fossil fuels** is lost when those fuels are burned in **power stations** to make electricity. Most of the energy is **lost** as heat.

A plane's flight data recorder, or ***black box****, is actually bright* ***orange*** *so that it is easy to spot after a crash. It can withstand temperatures of more than 1,823°F (1,000°C).*

The world's ***smallest guitar*** *is just 10 millionths of a meter long. It was made by Cornell University and produces* ***notes*** *17 octaves* ***higher*** *than a normal guitar.*

English scientist Sir Isaac Newton's dog ***Diamond*** knocked over a **candle** and started a fire that destroyed ***20 years'*** worth of his work.

The first *instant camera was made by* ***Polaroid*** *in 1948.*

Newton was one of the **greatest** scientists in history. He also invented the **cat flap**.

Any **Rubik's Cube** can be solved in **26** moves or fewer.

SEE WHAT ELSE SCIENTISTS HAVE DISCOVERED ON PAGES 88–125

Space

On a clear, **moonless night**, you can see about **2,500 stars** with the naked eye.

Uranus was discovered in 1781 and **Neptune** in 1846.

The gravity on the **moon's** surface is just **17 percent** of Earth's. If you can jump 3 ft (1 m) high on Earth, you would be able to jump 19 ft (6 m) on the moon.

*The **moon** moves just over **1 in** (3 cm) away from **Earth** each year.*

*The **moon** appears to be the same size as the **sun** from Earth because, although the sun is **400** times wider than the moon, it is also **400** times farther away.*

The sun contains more than 99 percent of all material in the solar system.

Space rockets need to reach a speed of **25,000 mph** (40,000 km/h) to escape the gravitational pull of Earth. This is called the **escape velocity**.

Earth is the densest planet in the solar system, with a density of 5.5 g/cm³ (3.2 oz/in³).

Jupiter is **1,321** times the volume of Earth. ***Mercury*** is just **0.05 times** the volume of Earth.

The clouds on Venus are made of sulfuric acid. Its atmosphere is 96.5 percent carbon dioxide.

The sun viewed from Mars is two-thirds the size of the sun viewed from Earth.

*In **winter** on **Uranus**, it is **dark** for **21 Earth years**.*

Saturn would **float** in a giant bath, since it is **less dense** than water.

Pluto was classified as a **planet** from its discovery in 1930 until 2006.

More than **22,500 meteorites** that landed on Earth have been **collected** and **cataloged**.

The **same side** of the **moon** always faces **Earth**. This is because the moon rotates in the same time as it takes to orbit—**27.3 days**.

The **dwarf** planet Ceres is the **largest** asteroid, at **600 miles** (960 km) across.

*The largest **volcano** in the **solar system** is **Olympus Mons** on **Mars**. It is **403 miles** (648 km) **wide** and **15 miles** (24 km) **high**.*

*Jupiter is **rotating** so quickly that it **bulges** in the middle.*

The ***Great Red Spot*** visible on the surface of **Jupiter** is a **storm**, wider than two Earths, that has been observed ***raging*** for the past **340 years**.

The **black hole** at the center of the Milky Way is as massive as **4.1 million suns**.

*There is no wind or rain on the **moon**, so **footprints** made by astronauts are likely to remain there for **millions of years.***

Neptune is the ***windiest*** planet. Gusts there can reach ***1,340 mph*** (2,160 km/h).

At a speed of 60 mph (95 km/h), it would take you 177 years to **drive to the sun**.

Astronauts are up to **2 in** (5 cm) **taller** in space because their **spines expand** in the **weightlessness**.

*It takes **84 Earth years** for **Uranus to orbit** the sun.*

The ***sun*** is ***halfway through its life***. It has been ***burning*** for ***4.6 billion years*** and will run out of fuel in ***5 billion years'*** time.

Our **sun** is orbiting the **black hole** at the center of the **Milky Way Galaxy** at a speed of **550,000 mph** (900,000 km/h). It takes **225 million years** to complete one orbit.

The universe is expandi**ng** in all directions at the speed of light.

*As we look into space, we see the **universe** as it was in the **past** because of the **time** it takes for the **light** of distant stars and galaxies to reach us.*

The tail of the **Great Comet**, which passed by Earth in **1843**, was more than **500 million miles** (800 million km) long—about the distance from the sun to Jupiter.

In 1971, US astronaut Alan Shepard stood on the **moon** and hit a **golf ball**.

Saturn's rings were first seen by **Galileo** in **1610** using one of the ***first-ever telescopes***.

Comet Encke is the most frequent visitor to Earth, passing by once every **3.3 years**.

There are more than **1 million asteroids** larger than 0.6 miles (1 km) wide in the Main Belt of asteroids between the orbits of Mars and Jupiter.

About every 50 million years, a meteorite more than 6 miles (10 km) in diameter hits Earth.

Two of the world's largest **optical telescopes** are found at the Mauna Kea Observatory in Hawaii. The twin **Keck** telescopes both have mirrors **33 ft** (10 m) in diameter.

*The **largest meteorite** on Earth is the **Hoba West**, which remains where it fell in **Namibia**, southwest Africa. It weighed **66** tons when it was found in 1920.*

*The **biggest stars** of all are **500 times larger** than the **sun** and **100,000 times as bright**.*

The **brightest** objects in the universe are ***quasars***—extremely distant galaxies that have incredibly bright centers. The quasars that we can see are so far away that their light has taken ***billions*** of years to reach Earth.

If you counted the stars in the **Milky Way** at a rate of one a second, it would take you about **5,000** years to count them all.

*Robert Goddard first suggested flying to the **moon** in a **rocket** in **1912**. People thought he was crazy.*

The planets of our **solar system** occupy a disk-shaped region extending **2.8 billion miles** (4.5 billion km) from the sun.

Astronauts on the **International Space Station** have been **growing plants** in space. The techniques they develop will be needed on any future mission to Mars, since the astronauts will need to grow their **own food**.

The ***Voyager 1*** spacecraft left Earth in 1977 and is now the most distant human-made object in space.

*Light from the sun takes just over **eight minutes** to reach Earth. The light from the next nearest star, Proxima Centauri, takes **4.3 years** to reach Earth.*

There is ***no sound*** in space, as sound cannot travel through a ***vacuum***.

Mars has **ice caps** at its **poles**, just like Earth.

*The largest canyon system in the solar system is **Valles Marineris on Mars**, which is more than **2,500 miles** (4,000 km) long.*

Volcanoes last erupted on the moon about 3.2 billion years ago.

The *Orion* vehicle is NASA's new spacecraft. From the early 2020s, it will carry astronauts to the **moon** and, later, on the first stage of a mission to **Mars**.

Yuri Gagarin's **mother** first found out about his **flight into space** when news of the mission broke.

It takes the Space Shuttle *eight minutes* to reach its orbital speed of 17,000 mph (*27,000 km/h*).

FOR MORE FACTS AND FIGURES ABOUT THE UNIVERSE, SEE PAGES 126–151

Earth

The rotation of Earth is slowing down, so days are becoming longer. In the age of the dinosaurs, **60 million years ago**, an **Earth day** was less than **23 hours long**.

At **midnight** on June 21 each year, it is **light** everywhere north of the **Arctic Circle**.

Looking out to **sea** from the **beach**, the **horizon** is about **3 miles** (5 km) away.

*After it was measured using satellites in 1999, the official height of **Mount Everest** was raised from **29,029 ft** (8,848 m) to **29,035 ft** (8,850 m).*

The **Great Barrier Reef**, at more than **1,200 miles** (2,000 km) long, is the largest living structure on Earth. It is even visible from space.

Nine out of 10 volcanoes are under the sea. More than 1,000 of the 1,500 active volcanoes in the world are in the South Pacific Ocean.

The pressure at the center of Earth is ***3 million*** times greater than that at the surface.

In the 20th century, the surface temperature of Earth rose by 1°F (0.6°C).

Coal is made from the compressed remains of plants that died **300 million years ago.**

When the volcanic island of **Krakatoa**, in Indonesia, erupted in **1883**, it could be heard a quarter of the way around the world.

Almost 20 percent of Earth's **oxygen** is produced by the **Amazon rain forest**.

*A large thunderstorm cloud, called a **cumulonimbus**, can hold enough water to fill **500,000 baths**.*

There are about **750** different species of **trees** in ***2.5 acres*** (one hectare) of the **Amazon rain forest.**

Over half the planet is covered by water more than 1 mile (1.6 km) deep.

Six million tons of **gold** are dissolved in the water of the world's oceans.

*In **1811**, an earthquake sent water in the **Mississippi River** flowing temporarily in the **wrong direction**.*

It would take a heavy object more than an hour to sink from the surface to the seabed at **Challenger Deep** in the Pacific Ocean, which is **36,201 ft** (11,034 m) deep.

The volume of water in the Pacific Ocean is the same size as the moon.

***Lightning** strikes Earth **100** times every second.*

China's Yellow River is the world's *muddiest* river. Two billion tons of mud wash down it every year.

Fresh snow is more than ***90 percent*** trapped air.

The biggest **desert** in the world, the **Sahara**, covers a **third** of the area of **Africa**.

Sand dunes move like waves across deserts at a speed of about 3 ft (1 m) per year.

*The lowest temperature ever recorded is **–128.5°F** (–89.2°C) at **Vostok, Antarctica,** on July 21, 1983.*

The highest temperature ever recorded was **134.1°F** (56.7°C) at **Furnace Creek, California,** on July 10, 1913.

The **strongest** gust of wind ever recorded blew at **231 mph** (372 km/h) on **Mount Washington** in 1934.

*The **driest** place in the world is the **Atacama Desert** in **Chile**. When it rained there in **1971**, it ended a **drought** that had lasted for **400 years**.*

The driest continent is ***Antarctica*** because it receives so little rain.

Seawater freezes at **–2°F** (2°C) because the salt in it lowers its freezing point.

There is enough **electricity** in a single fork of **lightning** to **light** a town for a year.

The surface of the **Dead Sea** in the Jordan Valley is 1,340 ft (408 m) below sea level. Its water is so **salty** that nothing can live in it except simple organisms, such as algae.

*The world's **shortest river** is the **North Fork Roe River**, in Montana; it is just **59 ft** (18 m) long.*

In **1873**, ***frogs*** rained down from the sky in Kansas City.

In **1948**, a group of golfers in Bournemouth, England, was showered with ***herring***. The animals had been swept up into the clouds by strong winds.

*The **hardness of rocks** is measured using the **Mohs scale**, with **soft talc** at **1** and **hard diamond** at **10**.*

The largest meteor crater is Vredefort in South Africa, which is 185 miles (300 km) wide. It was created when a meteor about 6 miles (10 km) wide collided with Earth 2 billion years ago.

As **deserts** grow larger, the amount of **land available** to grow **crops** is **shrinking** at a rate of **46,000 sq miles** (120,000 sq km) every year.

*Enough water to fill **2 million bathtubs** flows out of the **Amazon** River into the Atlantic Ocean in one second. This is **five times** as much water as the second-largest flow, from the **Ganges River**.*

On average, there are just **five days** a year when it doesn't **rain** on Mt. Waialeale in Hawaii.

On the afternoon of May 31, 1985, **41 tornadoes** were reported around the states of Pennsylvania and Ohio in the US. **Seventy-five** people were killed.

The eruption of **Mount St. Helens** in the US on May 18, 1980, set off an **avalanche** traveling at **250 mph** (400 km/h).

Earth's atmosphere is **430 miles** (700 km) thick.

Greenland is the **largest island** in the world, with an area of **836,109 sq miles** (2,133,086 sq km). **Australia** is **larger** but is considered to be a **continent** rather than an island.

*The **largest diamond mine** in the world is at Mirny in Siberia. The hole in the ground is **4,000 ft** (1,200 m) across—so big that **helicopters** are **sucked into it** if they fly too close.*

There are 14 mountains more than 26,000 ft (8,000 m) high, all of them in the Himalayas.

Clouds contain tiny droplets of water floating in air. A raindrop contains up to **2 million** cloud **droplets**.

A delay of **three seconds** between seeing **lightning** and hearing **thunder** means that the lightning is **half a mile** (1 km) away.

There are **15,000 bush fires** in Australia every year, as trees and shrubs burst into flames in the extreme heat. Many plants rely on these fires to release their seeds.

The **oldest rocks** in the **Grand Canyon** were formed **2 billion** years ago.

Over the last 10,000 years, **80 percent** of the world's **forests** have been **cut down** by humans.

No two ***snowflakes*** have the same shape, but they all have ***six sides***.

The Holderness coastline in east England is being eroded away by the North Sea at a rate of 5 ft (1.5 m) per year.

More than **30 percent** of **New Zealand's greenhouse gas** comes from methane in the **burps** and **farts** of the country's 45 million **sheep** and 10 million **cows**..

Seven percent of the world's **oceans** are covered in **ice**.

TO TAKE A CLOSER LOOK AT OUR PLANET, SEE PAGES 152–189

People and places

Vatican City isn't actually a city. It is a ***country***, although it's only as big as **50 football fields** and its official **population** is just **840 people**.

Nigeria is the most densely populated country in Africa with more than **197 million people**, but **Algeria** is the largest country geographically with a total area of **919,595 sq miles** (2,381,741 sq km).

Niger *has the youngest population in the world. More than half of its inhabitants are aged* ***18 or under****.*

Before humans arrived in ***New Zealand*** *around 1,000 years ago, there were* ***no mammals*** *there except bats.* ***Flightless birds****, such as the* ***kiwi****, walked the land instead.*

Singapore is both a city and a state. It is the only member of the UN with a completely urban population.

The bricks of the traditional **rondavel** houses of Rwanda are stuck together using **cow dung**.

China and India both have more than 1.3 billion inhabitants. The next biggest country by population, the US, has fewer than 330 million.

The city of **Troy** was thought to be **mythical** until its **ruins** were found in Turkey in the 1870s.

Istanbul *in Turkey is the only city to straddle* ***two continents****—Europe and Asia.*

The **tallest building** in the world is the **Burj Khalifa** in Dubai. It is **2,700 ft** (828 m) high, the tallest structure ever built by humans.

Damascus in Syria is the world's **oldest city**. People have lived there for more than 10,000 years.

There are 195 countries in the world.

There is ***enough stone*** *in the* ***Great Pyramid*** *in Egypt to build* ***a wall*** *3 ft (1 m) high around France.*

The flag of **Nepal** is the only national flag that is not rectangular. It looks like one **triangle** on top of another.

The soccer **World Cup** has only ever been won by countries from ***Europe*** or ***South America***.

It is estimated that **3.6 billion** people watched the **2016 Rio de Janeiro Olympics** on TV.

Mongolia *is the most* ***sparsely populated*** *country in the world. There are only* ***4.7*** *people per sq mile (1.9 per sq km).*

With **4 billion** viewers, **soccer** is the most-watched **sport** in the world.

Walmart, a US company with a chain of stores, is the largest company in the world with **2.3 million** employees.

France is the world's most **popular** vacation destination with more than **89 million** tourists each year.

Between 1800 and 2000, the population of the world grew from **1 billion** to ***6 billion***.

In 27 CE, **Rome** became the **first** city to have **1 million** inhabitants.

In 2008, for the first time in history, more than ***half*** *of the people of* ***the world*** *lived in cities and towns rather than rural communities.*

There are **50 states** in the US. The most recent to join was ***Hawaii***, on August 20, 1959.

Tokyo is the ***largest city*** in the world. If you include all its suburbs, its population is ***37 million***.

English is an offcial language in **67** countries.

There are about **110,000 Inuit people**, almost equally distributed between **Alaska**, **Canada**, and **Greenland**.

About *7,000 different languages* are used around the world, of which half are spoken by fewer than *10,000 people*.

The first map to name the newly discovered continent **America** was drawn by German cartographer Martin Waldseemüller in 1507.

Fewer than 100 people still speak **Votic**, a language of northern Russia.

More than 700 languages are spoken in Indonesia.

Australians eat more ***meat*** than anyone else.

Two million people converge on the holy city of **Mecca**, in Saudi Arabia, each year during the week of the Muslim pilgrimage called the **hajj**.

The ***oldest known map*** was drawn around ***2,500 BCE*** on a clay tablet in ***Babylonia***, in ***modern-day Iraq***, showing the area around the ***Euphrates River***.

Iceland's Althing is the oldest parliament in the world. Its first meeting was held in 930 CE.

*In 1978, Argentinian **Emilio Marcos Palma** became the first person to be born in **Antarctica**.*

About 4,000 people, mainly **scientists**, live in **Antarctica** in the **summer**. This number drops to 1,000 in the winter.

About ***1 billion*** people do ***not*** have enough to ***eat***.

Absolute monarchies are states that are ruled directly by a hereditary leader. **Saudi Arabia**, Brunei, Oman, and Swaziland are the only absolute monarchies that survive today.

*The **Trans-Siberian railroad** runs from **St. Petersburg** in the west to **Vladivostok** in the east. It is **5,772 miles** (9,288 km) **long** and goes through **eight different time zones**, without ever leaving **Russia**.*

There are more than **30** megacities with more than **10 million** inhabitants in the world.

The widest avenue in the world is **Avenida 9 de Julio** in **Buenos Aires**, Argentina. It has **12 lanes of traffic**.

At any given time of day, there are more than a ***million*** people in the ***air*** somewhere in the world.

*There are **1 billion bicycles** in the world, **400 million** of them in **China**.*

The United Nations was formed by **51** countries in **1945**. It now has **193** members since **Montenegro** joined in **2006**.

There are **55** different **ethnic groups** in **China** besides the Chinese.

Experts predict that India will overtake China as the most populous nation on Earth by 2030.

The first country to give women the vote was New Zealand in 1893.

Russia, the largest country by area, is almost twice the size of the second largest, Canada.

The first cell phone network was launched in Sweden in 1956.

The world's **busiest airport** is **Atlanta** in the US. More than **88 million people** pass through its doors each year.

About *half* of the world's people regularly eat *insects*. About *2,000* different species appear on the menu.

80 percent of the world's **toys** are made in **China**.

***The Rio de Janeiro Carnival** in Brazil is the world's biggest street party, with more than 2 million people packing the streets. London's **Notting Hill Carnival** in England is the second largest.*

FOR MORE AMAZING PEOPLE AND PLACES, SEE PAGES 190–225

History

An early **writing system called cuneiform** was developed in **Mesopotamia** (part of modern-day Iraq) around **3,100 BCE**. It was written by making wedge-shaped marks on clay tablets.

Modern humans settled in ***Australia*** at least ***10,000*** years before they reached Europe.

King Pepi II became ***king of Egypt*** in **2,275 BCE** aged just **6**. He ruled for **94 years** until his death aged **100**.

*The minimum period of **service** for legionaries in the **Roman army** was **25 years**.*

About ***2,000 years ago***, traded goods from ***China*** began to reach ***Europe*** and ***Africa*** along a route that became known as the ***Silk Road***, as silk was one of the goods traded.

In **1519**, the **Aztec capital *Tenochtitlán*** had a **quarter of a million** inhabitants. It was five times larger than London at the time.

*Of the **270 crew members** who set out from Lisbon with **Ferdinand Magellan** in 1519 to sail around the world, just **18** completed the journey. Magellan himself died halfway around.*

The Inca thought of gold as the sweat of the sun and silver as the tears of the moon.

The **Inca Empire** covered **350,000 sq miles** (900,000 sq km). In 1532, it was conquered by Spaniard Francisco Pizarro and just 168 men.

The ***first***-ever female head of state was ***Queen Merneith***, who ruled ***Ancient Egypt*** around ***3,000 BCE***.

The **Roman Empire** reached its greatest extent in **117 CE**, when it stretched from Britain in the northwest to the Persian Gulf in the southeast.

The* Roman *legal system is the basis for the* laws *of all countries in* Europe *and* Latin America*.

The gladiator **Spartacus** led a revolt of more than **100,000 slaves** against the army of the **Roman Empire** in **72 BCE**.

*The **Islamic calendar** started in **622 CE**. It uses a year that is 11 days shorter than a full solar year.*

Greenland was given its name by ***Viking chieftain Erik the Red*** around ***1000 CE*** in an attempt to attract settlers.

14th-century Arabian explorer **Ibn Battuta** traveled **73,000 miles** (117,000 km) and visited every **Islamic country** in the world.

In the census called the **Domesday Book** conducted in 1086, **10 percent** of the population of **England** were listed as **slaves**.

Polynesian sailors *crossed the Pacific Ocean **1,000 years** ago, using charts made of sticks to find their way.*

The Aztecs used cocoa beans as a form of money.

English explorer **Mary Kingsley** climbed ***Mount Cameroon*** in Africa on her own in 1895 when local guides refused to take her.

*The first English-speaking **colony** in **North America** was set up in **1585** in Roanoke in North Carolina. It lasted only one year.*

The **Ancient Chinese invented** many things. The so-called *"Four Great Inventions of Ancient China"* were ***paper***, the ***compass***, ***printing***, and ***gunpowder***.

*Between 1760 and 1840, **4,300 miles** (7,000 km) of **canals** were built in **Britain** to carry goods from the new factories around the country.*

Zimbabwe is named after the **ancient city** of Great Zimbabwe in southern Africa, **built of stone** between the 11th and 15th centuries, but then **mysteriously abandoned**.

People first settled **North America** around **20,000 years** ago. They walked across a land bridge that connected **northern Siberia** with **Alaska**.

The United States bought **Alaska** from Russia in **1867** for **$7.2 million**.

The **Statue of Liberty** was a present given by France to the US in 1877 to mark the **100th anniversary** of the ***American Declaration of Independence***.

*Between **1848 and 1855**, about **300,000** people went to **California** to find their fortunes in the **Gold Rush**.*

The longest-reigning monarch is currently **Elizabeth II** of the **UK**, who came to the throne in **1952**.

One century ago, **Ethiopia** was the only country in **Africa** that was not ruled by a European power. All African countries are now **independent** from Europe.

In the year 1900, **one-quarter** of the population of the **world** lived under **British rule**.

*Approximately **13 million** soldiers from **Russia** were killed in **World War II**, more than all other countries put together. More than **1 million** died in the siege of **Stalingrad** alone.*

King Richard II of England (1367–1400) threw extravagant **parties** for as many as **10,000 people** at a time.

In the 13th century, **Constantinople** and **Baghdad** were the largest cities in the world, with about **1 million** inhabitants each.

Japan's monarchy dates from **660 BCE** to the present day, during which time there have been **125 emperors.**

The earliest written **constitution** still in use in a republic today is that of the tiny European state **San Marino**. It dates back to **1600**.

*In the first factories and mines of the **Industrial Revolution** in Britain, children as young as 5 worked **16-hour shifts**.*

The Hundred Years' War between France and England actually lasted *116* years, from 1337 to 1453.

In 1783, a **sheep**, a **duck**, and a **rooster** became the first aircraft passengers when they **flew** in the Montgolfier brothers' **hot-air balloon.**

*The **Viking** law court was called **the Thing**.*

*In **medieval European courts**, animals could be tried for crimes. A swarm of **locusts** were once **convicted**, in their absence, of illegally eating crops.*

Between 1793–1794, at least **17,000** people were executed in the nine-month-long **"Reign of Terror"** during the ***French Revolution***.

*The **Black Death**, an outbreak of the bubonic plague, reached **Sicily** in southern Europe in **1347**. Less than three years later, it had spread to the **Arctic Circle**, 2,200 miles (3,500 km) to the north.*

The toilets of ***16th-century English*** homes were cleaned by a worker called a ***gong farmer***.

Of the *seven wonders* of the ancient world, only the *Great Pyramid of Giza* still exists.

The ***Great Plague of London*** ended in **1666** by the ***Great Fire of London***, which burned down the affected areas.

Ghamdan Palace in Sana'a, Yemen, built in the **3rd century CE**, may be the world's first-ever **castle**.

The **Great Wall of China**, built to protect China's northern border, is **4,000 miles** (6,500 km) long.

TO FIND OUT MORE ABOUT HOW WE USED TO LIVE, SEE PAGES 226–251

Art and culture

The first apartment buildings were built in **Rome** in the 1st century BCE.

***Eleven** Christian **churches** were carved out of solid rock at Labilela in **Ethiopia** in the 12th century CE. They took **24** years to complete.*

The **first**-ever **skyscraper** was the ***10-story***-high **Home Insurance Building**, built in **Chicago** in **1885**.

The ***Circus Maximus*** stadium in Ancient Rome could hold ***250,000*** people—a quarter of the population of the city.

In 1923, **marathon dancing** competitions became popular in the US after Alma Cummings danced for **27 hours** without stopping.

After a performance of the opera **Otello** *in Vienna, Austria, in 1991, starring Spanish tenor* ***Placido Domingo****, the audience* ***applauded*** *for* ***1 hour 20 minutes.***

Irish-born James Devine is the world's fastest **tap dancer**. He made ***38 taps per second*** in a performance in Sydney, Australia, in 1998.

Ancient Greek theaters were open-air. The biggest could hold 10,000 spectators.

Agatha Christie's whodunnit play **The Mousetrap** *has been playing in London's West End since 1952. There have been more than **27,500** performances so far.*

The ***"Whirling Dervishes"*** of the Sufi order of Islam perform their ***spinning dance*** as an aid to religious **meditation**.

*In the Mayan **ballgame court** at Chichen Itza, the acoustics are so good that a **whisper** at one end of the court can be heard at the other end **500 ft** (150 m) away.*

The **marble** and precious stones used to build the ***Taj Mahal*** in Agra, India, were carried there by ***1,000 elephants***.

In 2005, China had 39,425 movie screens—more than any other country.

The first modern novel was called **The Tale of Genji**, written **1,000 years ago** by Japanese author **Murasaki Shikibu**.

*Americans spend an average of **five hours** a day watching television.*

Playing cards date from ***12th-century*** **Persia** and **India**, when a pack contained ***48 cards***.

The most ***expensive film*** ever made was the ***Pirates of the Caribbean: On Stranger Tides***, with a budget of ***$378.5 million***.

The world's biggest movie screen is the **IMAX** in Sydney, Australia. It is as high as an **eight-story** building.

On average, it takes ***eight weeks*** to shoot a **Hollywood feature film**. Editing and adding special effects takes many months more.

French author Marcel Proust's novel **In Search of Lost Time** *contains just under 1.5 million words.*

The film **Gandhi** had **294,560 extras**.

The ***Harry Potter*** novels by J. K. Rowling have been translated into **80** different languages.

The epic ancient Indian poem *The Mahabharata* is four times longer than the Bible.

The **deputy electrician** on a film set is called the ***"best boy,"*** even when she's a girl.

The **biggest library** in the world is the Library of Congress in Washington, D.C., which has more than **32 million books**.

*The most prolific **novelist** in history was South African writer **Mary Faulkner**, who wrote **904 books**.*

The **Asterix** books, by French duo ***René Goscinny*** and ***Albert Uderzo***, have sold over 370 million copies worldwide.

English playwright ***William Shakespeare*** (1564–1616) is credited with inventing **1,700** new words.

The ***Codex Leicester***, one of ***Leonardo da Vinci's*** notebooks, was bought by US billionaire ***Bill Gates*** in 1994 for **$29 million.**

In May 1990, Dutch artist **Vincent van Gogh's** painting ***Portrait of Dr. Gachet*** sold for **$82.5 million**. In his lifetime, he was unable to make a living from his art.

*Italian artist **Michelangelo** spent **five years**, between 1536 and 1541, painting Biblical scenes on the walls of the **Sistine Chapel** in Rome.*

In 1872, Austrian composer **Johann Strauss** conducted an orchestra of **987 musicians** and a choir of **19,000 singers** in Boston.

*The slowest musical tempo is called **larghissimo**, Italian for as slow as possible. The fastest is **prestissimo**, meaning as fast as possible.*

The first permanent **photograph** was taken by **French inventor** *Nicéphore Niépce* in **1826.** It needed eight hours of exposure time.

An estimated 1.5 billion people watched the 1985 charity concert Live Aid on television.

The drawings of animals on cave walls in Chauvet, France, are approximately 36,000 years old.

The first museum to open its doors to the public was the **Uffizi Gallery** in Florence, Italy, in 1591.

In the 1930s, German company Blütner made a **baby grand piano** out of **aluminum** and **pigskin** so that it would be light enough to be carried in an **airship**. It weighed **400 lb** (180 kg).

The bestselling album of all time is **Thriller** by US pop star Michael Jackson, with an estimated 66 million copies.

*In December 2006, the **Netherlands** became the first country to **switch off** its analog **TV** signal, forcing everyone to use digital receivers.*

The lowest voice in opera singing is called a ***basso profundo***, Italian for "deep bass."

The term for actor, **thespian**, comes from the first actor known to history, Thespis from Ancient Greece.

The world's **largest statue** is the statue of Sardar Vallabhbhai Patel, one of the heroes of India's independence movement. The statue stands 600 ft (182 m) tall in the state of Gujarat, India.

*The first **compact disc** went on sale in 1982.*

La Scala opera house in Milan, Italy, has **3,600** seats.

It is now possible to watch more than 2,000 different TV channels from around the world online.

*The practice of awarding **caps** for international sports appearances started in England in **1886**. Soccer players in their first international were presented with a white **silk cap** with a red rose on the front.*

The highest paid sportsman of the **21st century** is ***Michael Jordan***, with earnings of around **$1.85 billion**.

The fastest ball game in the world is **pelota**, played in the Basque region of northern Spain and southern France. The ball can move at up to **180 mph** (300 km/h).

Athletics was the first sport to hold organized **competitions**. The first such event probably took place in Ancient Greece **5,000 years ago**.

Walt Disney was nominated for ***64 Oscars*** and won ***26***, more than anyone in history.

*On December 31, 1994, British pop singer **Rod Stewart** played a concert on **Copacabana Beach**, Rio de Janeiro, Brazil, to an estimated **3,500,000** New Year's Eve revelers.*

The **marathon** is a race run over a distance of **26.218 miles** (42.195 km). This is the distance Greek soldier ***Pheidippides*** ran without stopping from the town of Marathon to Athens in 490 BCE to announce victory in battle over the Persians.

Over its **21** separate stages, **12 million** people came out to watch the ***Tour de France*** bicycle race in 2017.

The English language has about **500,000** words, compared to **185,000** in German and **100,000** in French.

LEARN MORE ABOUT ART AND CULTURE ON PAGES 252–279

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